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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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100 Tube Keys.
100 Keys for pile head cap.
100 Keys for top of cap.

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Tenders, addressed as noted on the form, must be delivered at the Office of the Board not later than 2.30 p.m., on Wednesday, 12th May.

By Order,
DUNCOMBE MANN,
Clerk to the Board. G 104

METROPOLITAN BOROUGH OF HAMMERSMITH.

ELECTRICITY DEPARTMENT.

The Borough Council invite

Tenders for the Supply of

TWO 10,000 Kilowatt Maximum Continuous Rating TURBINES and Alternators, complete with Condensing Plant.

Specification and Form of Tender may be obtained from Mr. G. G. BELL, Borough Electrical Engineer, Electricity Works, 85, Fulham Palace Road, W. 6.

Sealed Tenders, endorsed "Tender for Turbines," must be delivered to the undersigned not later than Nine a.m., on Friday, 21st May, 1920.

The Council do not bind themselves to accept the lowest or any Tender.

LESLIE GORDON,
Town Hall, Hammersmith, W. 6. Town Clerk.
27th April, 1920. G 204

G. R.

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(PLANT AND MACHINERY SECTION).

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Full particulars and Tender Forms may be obtained on application to the CONTROLLER, Plant and Machinery Section, Charing Cross Embankment Buildings, London, W.C. 2.

Reference, Gen. 2265.

Tenders close at Ten a.m., on 5th May next.

NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 3d., at all bookstalls; or by quarterly subscription of 2s., post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. F 505

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(PLANT AND MACHINERY SECTION.)

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G. R.

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BY DIRECTION OF THE DISPOSAL BOARD.
(PLANT AND MACHINERY SECTION).

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Three LIFTS, Spiral Guided:
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Two STEEL TANKS, 75 ft. by 22 ft., 6 in.

Reference M.K. 24568/9. Gen. 2017.

Full particulars, permit to view, and Form of Tender upon application to the CONTROLLER (D.B.I.e.), Plant and Machinery Section, Charing Cross Buildings, Embankment, W.C. 2.

Tenders to be completed and returned not later than Ten a.m., 22nd May.

NOTE:—For particulars of other Government Property for Sale, see *Surplus*, price 3d., at all Bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 172

ELECTRIFICATION OF MELBOURNE SUBURBAN RAILWAYS.

THE AGENT GENERAL FOR VICTORIA is prepared to receive

Tenders for—

FOUR 4500 KW. 1500 VOLT TRACTION CONVERTER SETS
and
EIGHT 1000 KW. 1500 VOLT TRACTION CONVERTER SETS

for use in connection with the Electrification of the Melbourne Suburban Railways now being carried out.

Specification and Form of Tender which is issued separately for each size may be obtained from the Agent General for Victoria on application. Any *bona fide* Tenderer requiring information in addition to that contained in the Specifications, may apply to the Consulting Engineers, Messrs. MERZ & MCLELLAN, 32, Victoria Street, Westminster, S.W. 1.

The charge for the Specifications in duplicate is £5 5s. 0d. each and £3 3s. 0d. each for any further copies. Sums paid for the original Specifications (in duplicate), but not for further copies, will be refunded on receipt of a *bona fide* Tender for the whole of the works included in the Specification.

Sealed Tenders in duplicate marked "Electrification of Melbourne Suburban Railways—Tenders for Traction Converter Sets" are to be addressed to the AGENT GENERAL and delivered at his office, Melbourne Place, Strand, W.C. 2, not later than 12 noon on 31st May, 1920.

The Government do not bind themselves to accept the lowest or any Tender and ample security will be required from the Contractor whose Tender is accepted. G 196

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HANDLING PLANT at Belvedere Wharf, Southampton.

Plant Comprises:—

Two BOILER TANKS, about 80 ft. long by 5 ft. 6 in. diameter.

Two Babcock & Wilcox WATER TUBE STEAM BOILERS, each with 1827 sq. ft. heating surface and superheater.

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Main Steam Pipes in Boiler House.

COAL BUCKET, RUNNER BAR and FIXINGS, with lifting blocks and chains.

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30 B.HP. Motor Spare Armature, Switch Panel and Fittings, Two Sets of Spur reducing Gear, Two friction Drums, Two Rope Pulleys on heavy steel girder framing.

TENSION FRAME and Gear.

SHIP'S STEAM WINCH, Cylinders 8 in. by 12 in. stroke, Double geared with wire Hauling Rope.

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THREE-THROW PUMP, with 3½ in. rams, worm reducing Gear.

C.I. Box Stands on large base plate.

Switch Gear.

HYDRAULIC ACCUMULATOR, 8 in. ram, with about 5 ft. lift and seven C.I. ring weights.

COAL HOIST and TIP GEAR to lift a Railway Wagon and 12 ton of Coal about 44 ft. high. Steel framing. Top staging. ELECTRIC MOTOR, 50 B.HP., 110 volts, 600 r.p.m. Reducing Gear. Spare Armature.

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Horizontal, Vertical and Diagonal Rolled Steel Joist Framing.

Timber Flooring.

Corrugated Sheet Iron Walls and Roof.

One spare Timber built Pontoon Tank.

Coal Conveyor, 7 ft. wide by about 78 ft. effective length enclosed in steel casing.

Top and Bottom Rollers, Hinged Steel Carrying Plates, Adjusting Gear, Balance weights and framing at tail end.

ELECTRIC MOTOR, 30 B.HP., 110 volt, 600-800 r.p.m.

Switch Gear.

Two Countershafts, pulleys and fixings.

One 20 ton RAILWAY WAGON WEIGHING MACHINE, with Plate 12 ft. long, by Pelley.

Two HAULAGE TROLLEYS.

Tenders for the purchase of the whole or any of the items to be sent to JOHN GATES, Esq., West End, Southampton, not later than 10th May, 1920, from whom cards to view may be obtained. F 990

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:—

	Fee for Specification.
1. Cast Iron Sleepers	£1
2. Cast Iron Chairs	10/-
3. Steel Fishbolts, Spikes, etc.	7/6
4. Gibs and Cotters	5/-
5. Crank Fishplates	7/6
6. Water Cranes	5/-
7. Fencing Materials	7/6
8. Bolts, Nuts, Rivets, etc.	10/-
9. Brake Rigging	5/-
10. Anvils	5/-
11. Ramps	5/-

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Cast Iron Sleepers," or, as the case may be, not later than Eleven o'Clock a.m., on Tuesday, 11th May, 1920.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Cepthall Avenue, E.C. 2.
London, 28th April, 1920. G 242

FOR SALE.

CLACTON URBAN DISTRICT COUNCIL.

ELECTRICITY DEPARTMENT.

PLANT FOR SALE.

The above Council

Offer for Sale the following

PLANT:—

Two Davey Paxman, 160 B.HP., each engine Double-Cylinder "Vis a Vis" Q Type GAS ENGINES, direct coupled to 10 Kw. Thomas Parker's compound direct current generator, four-pole machines, to give 220 amperes with voltage regulation from 460-500 volts.

The plant is complete and can be seen by appointment.

Full particulars can be obtained from Mr. GEORGE BROADHURST, A.M.Inst. M.E., Electrical Engineer and Manager, 14, Electric Parade, Clacton-on-Sea.

Tenders to be delivered to the undersigned, Clerk to the Urban District Council, Town Hall, Clacton-on-Sea, not later than noon, on Monday, 17th May, next.

The highest or any Tender not necessarily accepted.

GEO. T. LEWIS,
Town Hall, Clerk to the said Council.
Clacton-on-Sea.
April 22nd, 1920. G 115

SHEFFIELD CORPORATION WATER WORKS.

RIVER DON PUMPING SCHEME—CONSTRUCTION OF RESERVOIR.

Tenders are Invited for the

Construction of a BALANCING RESERVOIR,

at Damflask, about 4 miles from Wadsley Bridge Station (G.C.Ry.), of a capacity of .84 million gallons.

Drawings and specification may be inspected, and schedule of quantities and Form of Tender may be obtained on application at the Water Works Office, Town Hall, Sheffield.

The Tender will incorporate Conditions of Contract, which provide (inter alia) for compliance with the Council's form of clauses respecting wages, hours and conditions of labour, and prohibition against assigning or sub-letting.

Tenders must be enclosed in sealed envelope, addressed to the undersigned, and endorsed "Tender for Damflask Balancing Reservoir," and received not later than Saturday, 22nd May.

The Corporation do not undertake to accept the lowest or any Tender.

WILLIAM THERRY,
Waterworks Office, General Manager.
Town Hall,
Sheffield.
23rd April, 1920. G 144

METROPOLITAN WATER BOARD.

DISPOSAL OF SPARE PLANT.

The Metropolitan Water Board invite

Tenders for the Purchase and

REMOVAL of

Three No. 4 ROOTS BLOWERS, manufactured by Messrs. Thwaites Bros., Ltd., 2912 pattern, each having a capacity of about 4000 cub. ft. per minute at 21 in. water gauge. Driven by Three Messrs. Siemens, Ltd., D.C. Motors, 11·5-27 HP., 220 volt, 388-1600 revs. per minute. Comp und wound with communication poles; two field regulators; two starters; three two-pole switches and ammeters. Also two W.I. cylindrical air holders, each having a capacity of 3550 cub. ft. diameter 17 ft. 9 in. by 14 ft. 9 in. deep. Crown plates ¼ in. thick, side plates ⅜ in. thick, fitted with relief valves, guide rollers and guides,

fixed at King George Pumping Station, Enfield Lock, Middlesex.

The Plant may be seen at the address stated at any time between Nine a.m. and Five p.m. on weekdays (Saturdays excepted) on application to the Engineer in charge of the Works.

A schedule containing particulars of the Plant, together with Tender Form and Conditions of Contract, may be obtained from the Chief Engineer by personal application, or on receipt of a stamped addressed envelope.

Tenders, which must be on the official form, addressed to "The Clerk, Metropolitan Water Board, South Place, Finsbury, E.C. 2," endorsed "Spare Plant," must be delivered at the offices of the Board not later than Four p.m. on Monday, the 10th May, 1920.

The Board do not bind themselves to accept the highest or any Tender.

A. B. PILLING,
Clerk of the Board.

Offices of the Board,
2, South Place,
Finsbury, E.C. 2.
22nd April, 1920. G 138

COLLISION DYNAMICS.

By G. GREENHILL.

"THE fashion to-day is to begin the study of dynamics with kinetics, and to treat statics as a special case in which acceleration is zero, and impact the special case where large forces act for a short period of time. But this is distinctly a recent movement."

Continuing this quotation from a stimulating letter by Professor E. B. Wilson to *Science*, October 15, 1915, on "Elementary Mechanics": "The old method was to study first statics and problems in impact, and therefrom to proceed to kinetics. The reason for this order was probably not wholly logical, but largely pedagogic and historical. A student with little (or no) knowledge of trigonometry is quite fitted mathematically to study statics, and problems in impact; whereas to obtain valuable training in kinetics a knowledge of the differential and integral calculus is necessary, including some differential equations."

As a matter of history, statics and impact precedes kinetics (Huygens enunciated the theory of collision in the Phil. Trans., 1669, eighteen years before the "Principia). Smeaton's experiments, Phil. Trans., 1776, 1782, published by Tredgold 1823, should also be consulted.

"Let us suppose the student has followed this historical and pedagogic order. In his statics he will have learned to deal with forces; these forces may be measured in any unit that is convenient, provided only that all the forces are measured in the same unit in the same equation; for the equations of statics are homogeneous in the forces. . . . In studying impact the fundamental conception is that of momentum. The student learns that momentum is the product of mass by velocity; that momentum is resoluble as are forces; and that in impact the momentum of a system is conserved. He is then in a position to solve problems on inelastic impact of particles, and with an additional simple law concerning relative velocity, he can proceed to elastic impact. In the problems on impact the unit of mass may also be anything, provided again that it is the same for all the masses. (Force and mass, the active and passive in mechanics). . . . The important thing for the student and his teacher is to keep as close to everyday life as possible, and any student knows what a weight of 4 lb is, so that he can proceed to statics. Moreover, he finds no difficulty in measuring the mass or "quantity of matter" (irrespective of quality) by weighing it, so that again he can proceed to problems in impact, The philosophy of mass or force will appeal to him much more after he knows something about mechanics. Our first problem is to get the student into a position where he can solve such simple problems of mechanics as he sees in the actual world on every side of him (as of a railway train or a flying machine); and a certain amount of ignorance, which would be lamentable on the part of his instructor, is highly praiseworthy in the student."

"Man must act first before proceeding to discuss the *rationale* of his activities."—A. N. Whitehead.

He can restrict himself a long time at the outset to Linear Dynamics, as of a train on a straight stretch of railway, or a carriage or bicycle on the road, of a shot up the bore of a gun, or the piston in a cylinder; and then there is no need to limit the size of a body to an invisible particle or heavy point, while geometrical difficulty is removed or delayed.

1. To fix the ideas of the beginner then on a visible case on a large tangible scale, take an object such as a railway carriage, wagon, or truck, on a straight line, and read or measure its weight W, in tons (in the weighing machine, its commercial weight), and its velocity v, in feet per second (f/s).

It is agreed to call the quantity $W\frac{v^2}{2g}$ the kinetic energy (K.E.), and to measure it in foot-tons, W being the tons, and $h = \frac{v^2}{2g}$ the feet of free vertical fall under gravity g to acquire the velocity v. That is, the body has the velocity v sufficient to raise it $h = \frac{v^2}{2g}$ feet vertical, and to use up the W h foot-tons of energy.

Next suppose there are two such trucks on the line, weighing W_1 and W_2 tons, and moving the same way with velocity v_1 and v_2, f/s.

The total energy of $W_1\frac{v_1^2}{2g} + W_2\frac{v_2^2}{2g}$, ft-tons, can be re-written, by an algebraical rearrangement:

$$(W_1 + W_2)\frac{V^2}{2g} + \frac{W_1 W_2}{W_1 + W_2}\frac{(v_1 - v_2)^2}{2g} = A + B,$$

where

$$(W_1 + W_2)V = W_1 v_1 + W_2 v_2, \quad V = \frac{W_1 v_1 + W_2 v_2}{W_1 + W_2},$$

so that V is the velocity of the centre of gravity (C.G.) of the two trucks.

We prefer, for historical continuity, to keep to Aristotle's name, centre of gravity, *κέντρον βάρους*, and not to employ any of the recent substitutes, such as mean centre, centroid, centre of mass, mass centre, centre of inertia, and so on.

In the rearrangement of the K.E. of the two trucks into the two terms A and B,

$$A = (W_1 + W_2)\frac{V^2}{2g} = \frac{(W_1 v_1 + W_2 v_2)^2}{(W_1 + W_2)2g}$$

is the K.E. of the whole weight, concentrated at the centre of gravity and moving with its velocity, and it may be called the molar energy; while

$$B = \frac{W_1 W_2}{W_1 + W_2}\frac{(v_1 - v_2)^2}{2g}$$

is the internal molecular energy, as it may be called, the energy relative to the C.G., as seen by writing it:

$$W_1\left(v_1 - \frac{W_1 v_1 + W_2 x_2}{W_1 + W_2}\right)^2\frac{1}{2g} + W_2\left(\frac{W_1 v_1 + W_2 v_2}{W_1 + W_2} - v_2\right)^2\frac{1}{2g} = \frac{W_1 W_2}{W_1 + W_2}\frac{(v_1 - v_2)^2}{2g} = B.$$

In any collision between the two bodies, which may take place at the buffers if one truck overtakes the other, or if the trucks are separating, the action may be supposed to act through a coupling chain becoming taut, the velocity of the centre of gravity, the momentum, and the molar energy are unaltered.

If W_1 overtakes W_2, and at the moment of collision the two trucks are coupled up, they move together with the molar velocity of the C.G., and the velocity of separation is reduced to zero; the internal molecular energy, B ft-tons, has been dissipated or liberated, say in compressing the buffer springs, and the impact appears inelastic. We are not entitled to assume the buffers perfectly inelastic; there is no such substance in Nature. They may behave as if inelastic, as a spring compressed and not released; or as soft and plastic, like cushions, or hot iron hammered on the anvil.

Conversely with this amount of energy B acting explosively, as in the bore of a gun, when the two are moving together, the original molecular energy would be acquired, as with springs perfectly resilient, and the bodies separate with their original velocity of approach; and denoting their velocity on separation by u_1 and u_2:

$$u_2 - u_1 = v_1 - v_2, \text{ with } W_1 u_1 + W_2 u_2 = W_1 v_1 + W_2 v_2,$$

$$u_1 + v_1 = u_2 + v_2 = 2\frac{W_1 v_1 + W_2 v_2}{W_1 + W_2}.$$

2. In Newton's experimental law of rebound, the velocity of separation after collision is a constant fraction e of the velocity of approach, and e is called the coefficient of restitution; then:

$$u_2 - u_1 = e(v_1 - v_2),$$

$$u_1 + e v_1 = u_2 + e v_2 = (1 + e)\frac{W_1 v_1 + W_2 v_2}{W_1 + W_2}.$$

The molecular energy after collision is:

$$B' = \frac{W_1 W_2}{W_1 + W_2}\frac{(u_2 - u_1)^2}{2g} = e^2\frac{W_1 W_2}{W_1 + W_2}\frac{(v_1 - v_2)^2}{2g} = e^2 B,$$

and the fraction $1 - e^2$ of the internal molecular energy has been dissipated or liberated at the impact, Also:

$$\frac{W_1 u_1 + W_2 u_2}{W_1 + W_2} - u_1 = e\left(v_1 - \frac{W_1 u_1 + W_2 u_2}{W_1 + W_2}\right)$$

$$u_2 - \frac{W_1 u_1 + W_2 u}{W_1 + W_2} = e\left(\frac{W_1 u_1 + W_2 u_2}{W_1 + W_2} - v_2\right)$$

that is, in each body the velocity relative to the C.G. has been reduced after collision by the factor e; that is the impulse at the impact may be divided into two parts, X during the time of the inelastic collision, while the relative velocity is reduced to zero, and e X while the relative velocity is regained (during restitution), to e times its former amount.

3. In a case of perfect resilience, we may assume the "Law of the Spring." It is time the name "Hooke's Law" was dropped, expressed in the absurd Latin "*ut tensio, sic vis.*"

Proceeding then in the illogical manner of taking for granted what can be proved at leisure hereafter, and taking the thrust as F tons when the buffers are compressed to their maximum a, feet, the average thrust $\frac{1}{2}$ F tons acting through a feet on each buffer requires F a ft-tons of work, and this is provided by the internal energy B:

$$F a = \frac{W_1 W_2}{W_1 + W_2}\frac{(v_1 - v_2)^2}{2g}.$$

During the impact against this variable spring resistance, the average velocity of approach is $\frac{v_1 - v_2}{\frac{1}{2}\pi}$, and not $\frac{1}{2}(v_1 - v_2)$, as it would be against uniform resistance, and so the impact during compression and rebound lasts:

$$\frac{2a}{\frac{v_1 - v_2}{\frac{1}{2}\pi}} = \frac{\pi a}{v_1 - v_2} = \pi\sqrt{\frac{1}{g}}\sqrt{\left(\frac{1}{\frac{F}{W_1} + \frac{F}{W_2}}\right)}$$

the beat of a pendulum of length:

$$\frac{\frac{1}{4}a}{\frac{F}{W_1} + \frac{F}{W_2}} = \frac{\frac{1}{4}W_1 W_2}{W_1 + W_2}\frac{a}{F},$$

and this is constant on the proportionality of a to F, the Law of the Spring; thus the impact lasts the same time whatever the velocity of approach, $v_1 - v_2$.

On Newton's law of rebound, $u_2 - u_1 = e(u_1 - u_2)$, F must be replaced by e^2F in hysteresis of the recovery of the spring, and the rebound lasts longer than the compression, as one to e.

So also pile driving into ground may be considered, against uniform resistance, or resistance growing uniformly with the depth of penetration; or on a small familiar scale, in driving a nail into wood with a hammer.

To stop for a moment to explain why this value has been taken of the average velocity, we assimilate the motion of the buffer to a piston in a cylinder, describing the stroke $2a$ ft twice over, while the crank moves round a circumference $2\pi a$ of radius a, with constant velocity, equal to the maximum piston velocity; or else to the bob of a pendulum swinging to and fro', accompanied by another pendulum bob moving as a conical pendulum in the same period.

Then (as shown on Fig. 6, to be given later), while the point P, the crank-pin, goes round the circle A P A' in a complete circuit with the velocity V, the point M on the piston rod describes the diameter A A' twice over, to and fro', passing through the centre O of its stroke with its maximum velocity equal to V. Thus U, the average velocity over A A' is such that:

$$\frac{V}{U} = \frac{\text{circumference}}{\text{twice diameter}} = \frac{2\pi a}{4a} = \frac{1}{2}\pi, \quad U = \frac{V}{\frac{1}{2}\pi}$$

4. The large steel spheres employed as ball bearings in heavy machinery are suitable for experimental illustration, suspended by a long thin wire from a staple screwed in the surface; a blow-pipe will remove the hard temper at a spot where the surface is to be screwed and tapped for the staple. With wires of equal length and the spheres suspended in contact hanging vertically, the isochronism of the pendulum may be assumed if the length is large enough; and the balls collide at the middle point of the swing and position of equilibrium, if released at the same moment.

In this way the direct and oblique impact can be shown off and measured with spheres, equal or unequal in weight or size, as the spheres always strike square.

Also the successive impacts are heard, smaller and smaller in geometrical progression according to our theory, infinite in number although accomplished in a finite time, and so the convergence of a series is demonstrated mechanically.

An estimate of the deformation and average thrust in contact is inferred from a measurement of the circle marking the area of contact on a film of oil or paint in the compression.

If a sphere hangs plumb at C and is drawn aside

to A and let go, it will reach C with a velocity proportional to A C; and this is the velocity which turned through a right angle at A will carry the sphere round in a horizontal circle, as the bob of a conical pendulum.

5. The geometrical method given in Maxwell's "Matter and Motion," lxxix, of the rearrangement of the energy of two bodies into the two parts, molar and molecular, may be extended to the oblique collision of our two elastic spheres.

In the velocity diagram, Fig. 1, vectors O V_1, O V_2 are drawn, from O the contact of the spheres, to represent the velocities before impact, and then O G to the C.G. of the weights W_1, W_2, at V_1, V_2, will represent the velocity of the C.G.

Then (dropping g for a moment) the kinetic energy may be represented to scale by:

$$\begin{aligned} \text{K. E.} &= \tfrac{1}{2} W_1 . O V_1^2 + \tfrac{1}{2} W_2 . O V_2^2 \\ &= \tfrac{1}{2} W_1 (O G^2 + G V_1^2 + 2 G V_1 . G D) \\ &\quad + \tfrac{1}{2} W_2 (O G^2 + G V_2^2 - 2 G V_2 . G D) \end{aligned}$$

in which

$$W_1 . G V_1 = W_2 . G V_2 ,$$

so that G D cancels, and

$$W_1 . G V_1^2 = \frac{W_1 W_2^2}{(W_1+W_2)^2} V_1 V_2^2 , \quad W_2 . G V_2^2 = \frac{W_1^2 W_2}{(W_1+W_2)} V_1 V_2^2 ,$$

so that the

$$\text{K. E} = \tfrac{1}{2} . (W_1 + W_2) OG^2 + \tfrac{1}{2} \frac{W_1 W_2}{W_1 + W_2} V_1 V_2^2 = A + B,$$

in accordance with the previous statement in § 1 for motion in the same line.

If the impact is inelastic and in the line O X, the relative velocity is changed from $V_1 V_2$ to $T_1 T_2$, where $T_1 T_2$ is perpendicular to O X, and $V_1 T_1$, $V_2 T_2$, parallel to O X; and O X is the vector of the component velocity of each body, and their C.G., along the line of impact; the relative velocity across the line of impact being $T_1 T_2$.

Draw $U_1 U_2$ to represent the relative velocity after elastic impact, where $V_1 T_1 U_1$, $V_2 T_2 U_2$, are parallel to O X; and on Newton's law of rebound, $T_1 U_1 = e$, $V_1 T_1$, $T_2 U_2 = e . V_2 T_2$; and then the velocity after impact is represented by the vector O U_1, O U_2.

If the experiment is performed with the spheres suspended by threads or wires of equal length, then O V_1, O V_2 may be taken equal to the length $A_1 C_1$, $A_2 C_2$, the spheres were drawn aside from their position C_1, C_2, hanging vertical, plumb; if let go at the same instant from A_1, A_2, the spheres will reach C_1, C_2, at the same instant and collide, and come to rest again for a moment at B_1, B_2, where $C_1 B_1$, $C_2 B_2$, are equal and parallel to O U_1, O U_2.

In a momentum diagram, draw G M_1, G M_2 parallel to O V_2, O V_1, and join $M_1 M_2$, bisected at H on O G.

Then O M_1, O M_2 can represent the momentum vectors of W_1, W_2; because, drawing $M_1 m_1$, $M_2 m_2$ parallel to $V_1 V_2$, cutting O G in m_1, m_2,

$$\frac{OM_1}{M_1 m_1} = \frac{OV_1}{GV_1} , \frac{OM_2}{M_2 m_2} = \frac{OV_2}{GV_2} , \text{ and } M_1 m_1 = M m_2 ,$$

$$\frac{OM_1}{OM_2} = \frac{OV_1}{GV_1} . \frac{OV_2}{GV_2} = \frac{GV_2}{GV_1} . \frac{OV_1}{OV_2} = \frac{W_1 . OV_1}{W_2 . OV_2} .$$

Also O G = 2. O H, the vector of molar momentum, and the molecular momentum is zero.

Draw $M_1 R_1 N_1$, $M_2 R_2 N_2$ parallel to O X, cutting O T_1, O U_1 in R_1, N_1, and O T_2, O U_2 in R_2, N_2; $M_1 R_1 = M_2 R_2$ represent the vector of momentum interchanged between W_1 and W_2 at inelastic impact; and $R_1 N_1 = e . M_1 R_1 = R_2 N_2 = e . M_1 R_1$, the gain and loss in the resilience of elastic impact.

In the familiar experiments in billiards on oblique collision, the two spheres are restricted to be ivory balls of equal weight, and roll on a horizontal table, struck by a cue.

Our object, however, is not to arrest the attention with lecture-room experiments, but to encourage the learner to take his ideas on a large scale, from what he sees in the micro-megaphysics of Nature at work.

6. In the preceding, much has been taken for granted, before it was defined and explained, but assumed as familiar to the reader. The final results of dynamics are found recorded in an engineer's pocket book. The logical order has been abandoned, but then "logic is a very poor substitute for common sense, and it is probably logic more than anything else that makes trouble with pedagogy in mathematics, and even more in mechanics and physics; it would be hard to try to be logical in theoretical chemistry." "There are various kinds of logic, one kind the mathematician's, which is adopted to a certain extent by others, the other logic being the logic of everybody else; a biologist has probably a logic very different from that of the mathematician, and very much more useful to him. From the pedagogic standpoint strict logic with all its beauties (which the student always misses) is the most illogical thing there is." Consult de Morgan's Calculus for a distinction between correct and logical.

But a French-trained intellect will never consent to abandon a strict logic, and confesses itself repelled by the Maxwell line of thought and reasoning.

Some revolt can, however, be discovered in "Appareils de mesures et d'observations, par H. Bouasse, Professeur à la Faculté des Sciences de Toulouse, 1917."

Bouasse has the audacity to point out some flaws in the original framing of the metric system, and to deride the regulations making the standards to be standard at the freezing temperature, and practically is a vacuum. As a result the comparisons are made in the most trying conditions, and so are liable to be hurried and scamped.

His interesting remarks are very outspoken, and precise academic colleagues will class him "*un enfant terrible*"; but he speaks a valuable message,

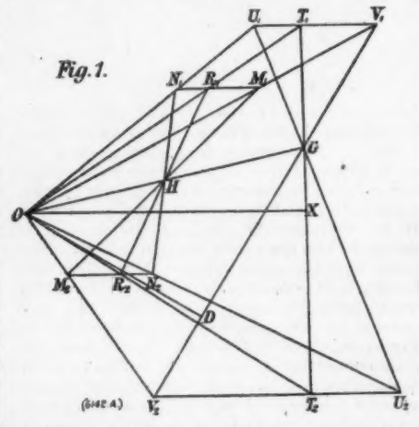


Fig. 1. (half A)

and delivers it with vigour and well-chosen invective. A book for the engineering student to appreciate.

"Je demande qu'on fasse la science avec ce qu'ils voient tous les jours.

Les appareils sont légion, les organes des appareils sont en petit nombre. Donc il font savoir les organes et se servir des appareils pour montrer leur rôle.

Tout appareil de laboratoire a dans l'industrie du similaire, peut être un peu moins précis, mais plus répandu, et meilleur marché.

A faire le choix, il est préférable de négliger les appareils de laboratoire plutôt que les appareils industriels, dont les usages sont plus nombreux.

La machine à diviser est intéressante, le microtome des naturalistes l'est davantage, la machine à découper les tranches de saucisson l'est encore bien davantage."

Compare Maxwell's remarks in his *Introductory Lecture on Experimental Physics* (*Scientific Papers* II, p. 242), on the two classes of experiment: Experiment of Illustration and Experiment of Research.

7. Encouraged by the logical heresies of Professor E. B. Wilson, we can proceed to examine more closely what takes place in the very short time during the impact, not only of two trucks, or billiard balls, but of hammer driving on a nail or pile, or in forging hot iron on the anvil; and to treat it as a penultimate case of dynamics, where the time can be observed easily during which the motion of a body is started, stopped, or changed, still keeping to the linear dynamics of motion in a straight line.

Invited to give an address to the Mathematical Club at Cambridge, I chose as the title "A Lecture of One Minute on Linear Dynamics"; intended to show how the theory and abstract formulas would go on to a sheet of note paper, enough to carry the beginner through his first year in dynamics, with plenty of application to familiar sights and experiment; such as I have collected in my "Notes on Dynamics."

A force, F pounds or tons, acting for t seconds through s feet on a body of weight W, pound or ton, (a railway truck, motor car or lorry, motor-bus, bicycle, boat, steamer, shot in a gun) will give it velocity v feet per second (f/s) from rest, such that:

$$\text{(A)} \quad \underset{\text{(lb or tons) (sec)}}{F \times t} = \underset{\text{(lb or tons) (sec)}}{W \times \frac{v}{g}} \qquad \begin{matrix} \text{(Impulse)} \\ \text{(Momentum)} \end{matrix}$$

$$\text{(B)} \quad \underset{\text{(lb or tons) (ft)}}{F \times s} = \underset{\text{(lb or tons) (ft)}}{W \times \frac{v^2}{2g}} \qquad \begin{matrix} \text{(Work)} \\ \text{(Energy)} \end{matrix}$$

and falling freely, in a field of gravity g, where F = W, v is acquired in falling $\frac{v}{g}$ seconds, through $\frac{v^2}{2g}$ feet, vertical.

The dynamical quantity $W \frac{v^2}{2g}$, the kinetic energy (K.E.), ft-lb or ft-ton, is the equivalent of the work $F s$; and $W \frac{v}{g}$, the momentum, is the equivalent of $F t$, which may be called impulse, measured in second-lb, or second-tons.

As the time t during which F is acting grows smaller, the impulse changes from a push, through a shove, into a blow, the equivalent momentum remaining the same if F is increased in proportion, so as to keep $F t$ constant.

Here a legal definition is required, as in an action for assault and battery, when the push changes into a shove, and the shove into a punch, kick, or blow.

The usual dynamical question of the superior mechanic, say an Arsenal foreman, generally resolved itself into some such distinction, asking for the steady pressure equivalent to a hammer blow, not to be answered till something more was specified about the duration of the impact.

One effective way, the Socratic, is to lead the man on to answer his own question.

Invited to look out of the window of a top story, ask him to choose the alternative, either to stay and be burnt to death by the fire supposed to have broken out, or to escape by the only way of jumping out of the window.

After a glance at the hard ground below, he will prefer to take his chance of the arrival of the fire escape. But then he changes his mind when he is assured of succour below, in blankets held out ready to receive him, which were not there when he looked out first. Thus he solves his own difficulty in the question by adding the unspecified nature of the bodies in contact at the blow.

The principle of momentum is stated first in (A), as more intelligible to the innate notions (Aristotelian) of the beginner; and it is a definite translation into an equation of Newton's second law of motion, given as a proportion:—

"Mutationem motus proportionalem esse vi motrici impressæ, et fieri secundum lineam rectam qua vis illa imprimatur."

"Change of motion is proportional to the impressed force, and takes place in the line of direction of the force."

In modern vectorial statement, the vector velocity of the momentum vector is equated to the force vector, a method applicable to motion of any kind.

Here "motus" is the "quantitas motus," quantity of motion of Definition II of the "Principia," "mensura ejusdem orta ex velocitate et quantitate materiæ conjunctim"—what is called now momentum.

And the change is estimated per unit of time (not of distance). A railway porter pushing a truck for double time will give it double velocity, or two porters pushing for the same time. And if pushing simultaneously on two equal trucks on parallel lines, the velocity imparted by each porter will be the same. So that double weight requires double force to get up the same velocity in the same time.

Newton states his Law II in the form of a proportion or variation, and does not reduce it to an

ARMSTRONG SHIPYARD; DOUBLE PLATE SCARFING MACHINE.

CONSTRUCTED BY MESSRS. HUGH SMITH AND CO., LIMITED, ENGINEERS, GLASGOW.

Fig. 124.

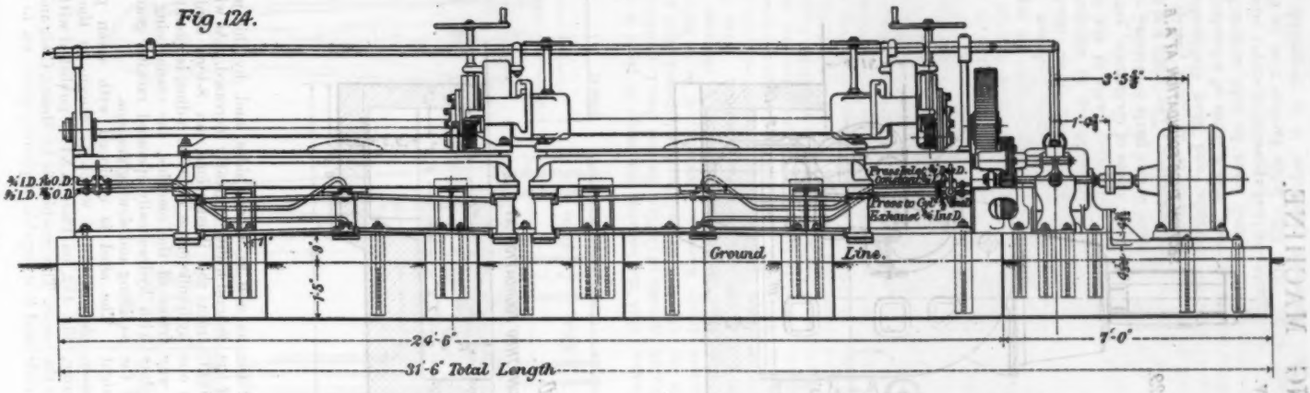
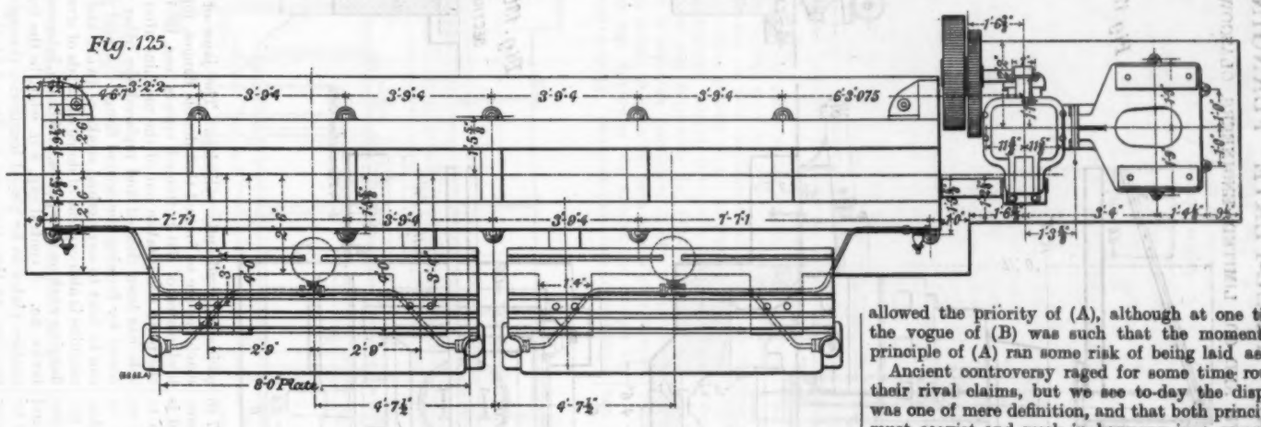


Fig. 125.



equation as in (A), as required if he went so far as to apply his law to a numerical case.

The elusive g then puts in an appearance in (A), and Absolute Measure of the theoretical writer is directed to the extermination of g; at a loss, however, of physical grasp. Much pious interpretation was read into this bald statement of Law II by Professor Tait, with a view of backing up his pronounced views on the exclusive use of absolute units in dynamics, as contrasted with the gravitation units of the engineer. But Tait did not carry his colleague Thomson with him in these views.

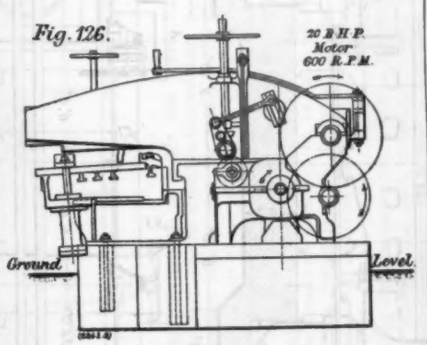
The electrician deals in cosmical dynamics, and so prefers absolute measure in metric units in his electromagnetic equations, and the two systems, gravitation and absolute, live in harmony together to-day; but the engineer will never abandon his gravitation units in dynamics, carried on from use in statics, in his vocation comparatively stationary.

All matter is transparent to gravity, and our senses are reminded of it at every moment. But they are insensible to magnetism, and a comparison of the effect was made in ENGINEERING, November 28, 1919, page 726.

The all-pervasive g in the dynamical equations of our existence here, on the surface of this Earth, was a worry to previous academic writers, all copying from each other and never reading outside their own treatises. They tried to hide g away under W, then replacing W/g by a single algebraical letter like M, and calling it the mass. Later on Perry proposed the name "slug" for the unit of this mass, something about a 32-lb shot, W being still measured in lb.

But Tait had appeared on the scene before Perry, in raising g to the other side of the equation, up on the level, and then exterminating it by a change of his unit of force to the absolute measure, in the poundal or dyne. He retained, however the former academic M, and still called it the mass, although Tait's device had made M into the old friend W

Fig. 126.



again, the weight in pounds. Thus Newtonian mass M and commercial weight W are only different names and letters for the same thing; and the distinction between them, insisted on so carefully, is a distinction without a difference.

There is still a third method of exterminating the all-pervasive g, by a change to a new unit of time, taking it as the fraction of a second for a body to fall 6 inches. In this system the dynamical equation

$$W \frac{d^2 x}{g\, dt^2} = X \text{ changes into } W \frac{d^2 x}{d T^2} = X,$$

as in absolute measure, with $g t^2 = \tau^2$, and then $\tau = 1$ when $\frac{1}{2} g t^2 =$ half a foot, six inches.

But this suggestion would raise universal outcry, and is not a practical proposition.

Between (A and B), division gives

$$(C) \quad \frac{s}{t} = \frac{1}{2} v, \text{ the average velocity.}$$

After (A) is stated, (B) or (C) may follow in either order, as they appeal to the logical sense of the learner.

But the principle of energy in (B) must not be allowed the priority of (A), although at one time the vogue of (B) was such that the momentum principle of (A) ran some risk of being laid aside.

Ancient controversy raged for some time round their rival claims, but we see to-day the dispute was one of mere definition, and that both principles must coexist and work in harmony in a complete system of dynamics.

Here the new Relativity comes on the scene, inviting us to reject the conservation of mass, retaining only the conservation of energy, and classing mass as an imponderable, as well as energy.

(To be continued.)

THE ARMSTRONG SHIPYARD.

(Continued from page 543.)

ONE of the interesting tools in the platers' shed to which special reference should be made is a double scarfing machine, engravings of which are given in Figs. 124 to 126, on the present page. As will be seen from the illustrations, the machine is provided with two tilting tables to which the plates to be scarfed are attached, the tables being planed on the upper surface and having tee slots for bolts. The provision of two tables enables the work to be carried on continuously, as, while the two saddles are engaged in planing the scarfs on one plate, another plate is being mounted on the second table, and, by the time the first plate is finished, the second plate is fixed and ready for planing. The two saddles are then moved together along the bed by means of a screw and suitable gearing, so as to bring them into position over the second plate, which is then scarfed while the first plate is being removed and replaced by a third plate, and so on. The tool slides, which have a stroke of 21 in., are driven by crank discs with steel connecting rods bushed with brass at both ends, and a quick return motion is obtained by a pair of eccentric gear wheels on each saddle. Each saddle is fitted with an independent self-acting feed motion, for feeding the cutting-tool across the plate, and each is provided with a separate stopping and starting gear; hand wheels and screws are provided for raising and lowering the tool-holders. The machine is driven by a 20-h.p. motor, running at 600 r.p.m., by means

ARMSTRONG SHIPYARD; HYDRAULIC KEEL-PLATE FLANGING MACHINE.

CONSTRUCTED BY MESSRS. HUGH SMITH AND CO., LIMITED, ENGINEERS, GLASGOW.

Fig. 127.

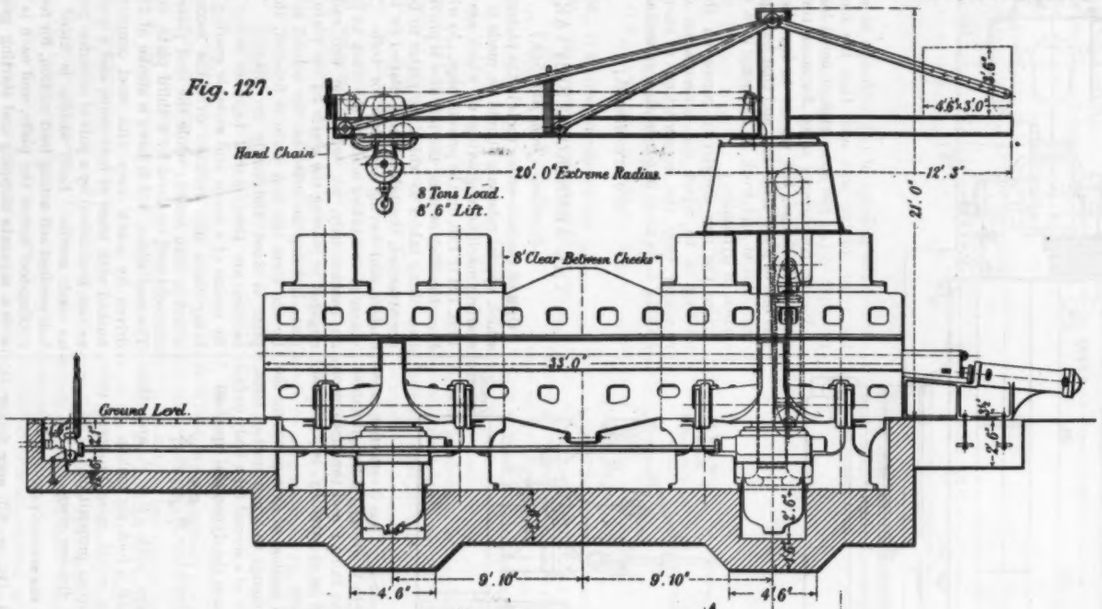


Fig. 128.

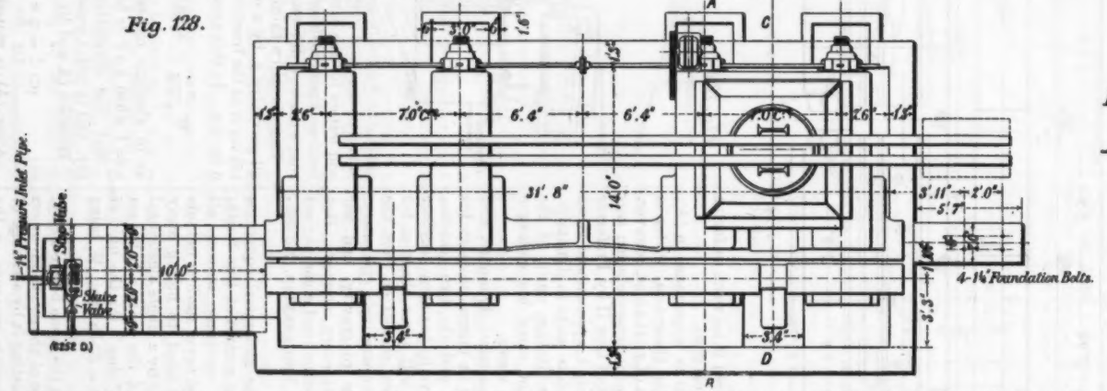


Fig. 129. SECTION THRO' FOUNDATION AT A.B.

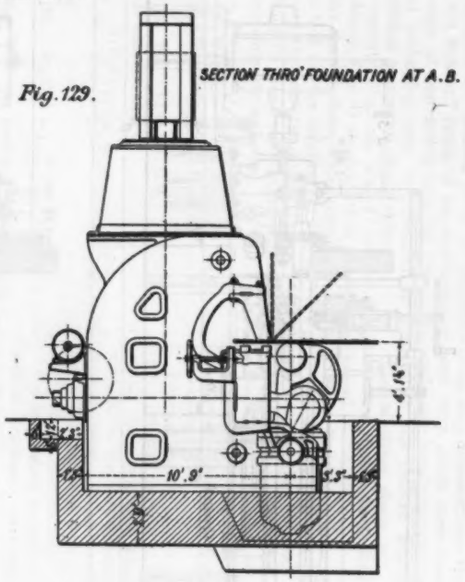
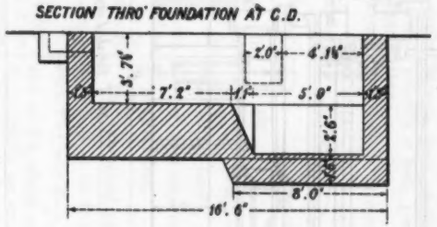


Fig. 130. SECTION THRO' FOUNDATION AT C.D.



of gearing, all of which is machine cut, except the eccentric wheels. The machine was supplied by Messrs. Hugh Smith and Co., Ltd., of Glasgow, and is capable of scarfing plates up to 8 ft. 6 in. in width.

After the plate-bending rolls dealt with in our last article, however, the largest and most important tool in the shed is the keel plate flanging machine, part of which is visible on the right of Fig. 115, on Plate XXXI, accompanying our issue of April 23. This machine, which is numbered 3 on the key plan, Fig. 119, on page 541 *ante*, is illustrated separately by the half-tone engraving, Fig. 133, on page 582, and by the line drawings reproduced in Figs. 127 to 130, on the present page. It was supplied by Messrs. Hugh Smith and Co., Limited, of Glasgow, and is capable of flanging cold high-tensile plates up to 33 ft. in length and up to 1 in. in thickness to an angle of 90 deg. Similar plates up to 1¼ in. in thickness can be flanged to an angle of 45 deg. The plate to be flanged is gripped in the jaws of the machine by means of wedges actuated by the hydraulic ram seen on the right of Fig. 127, and also in Fig. 133, and the flanging is performed by a heavy forged steel roller operated by two large oscillating hydraulic cylinders. The jaws of the machines are so formed that double flanges, for the keel plates of flat-bottomed vessels, can be bent, the plate being taken out of the machine after one side has been flanged and replaced the other way round for forming the second flange. A keel plate can be bent to any desired strake or twist, and the machine is also capable of doing all kinds of straight flanging work on floor plates, bulkheads, intercostals, tanks, &c. A central gap, 8 ft. wide, in the frame, enables plates to be placed lengthwise through the machine, so that they can be flanged at the ends as well as at the sides, and, by this means, its general utility is greatly increased. As will be seen from the illustrations, an 8-ton, semi-balanced hydraulic crane, of 20 ft. radius, is mounted on the frame of the machine, the crane being provided with hydraulically-operated racking gear, as well as lifting and slewing motions.

The shed is equipped with seven plate-edge planers, one of which is shown on the right of Fig. 112, on Plate XXIX, published with our last issue. This machine is by Messrs. Craig and Donald, and it is capable of planing plates up to 41 ft. in

ARMSTRONG SHIPYARD; PLATE-EDGE PLANING MACHINE.

CONSTRUCTED BY MESSRS. SMITH BROTHERS AND CO. (GLASGOW), LIMITED, ENGINEERS, GLASGOW.

Fig. 131.

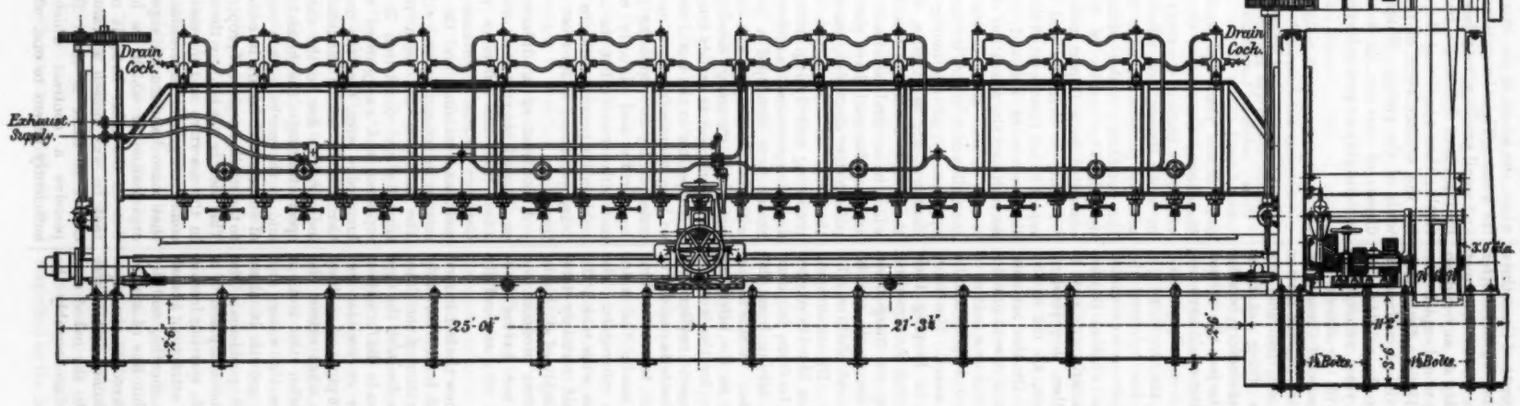
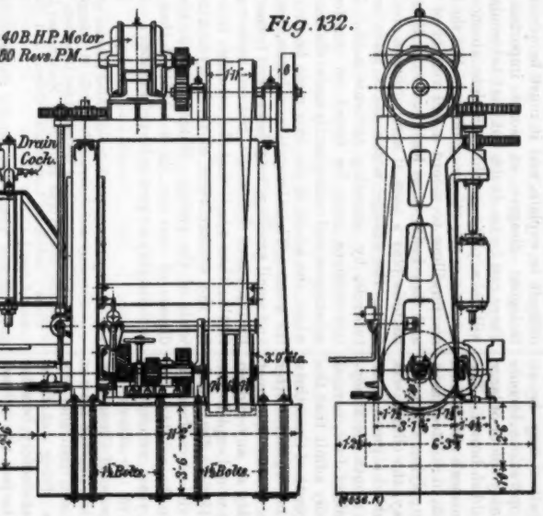


Fig. 132.



length and up to 2½in. in thickness. The most interesting tool of this class is, however, one by Messrs. Smith Brothers and Co. (Glasgow), Limited, of Glasgow. The special feature of this machine, illustrated in Figs. 131 and 132, annexed, is that the clamping girder can be raised to admit work, such as turbine-lifting girders, up to 2 ft. 3½ in. deep. The clamping girder, which, as shown, is provided with hydraulic clamping cylinders in addition to the usual screws, is raised and lowered by means of screws and worm gearing, at each end, operated by hand. The machine is driven by a 40-h.p. motor geared to a countershaft and erected on top of the entablature at the gearing end, as shown in the drawings. Open and crossed belts transmit the drive from the countershaft to the machine pulleys, and two cutting speeds of 15 ft. per minute and 30 ft. per minute are obtained by means of gearing. The latter speed is used for planing mild steel plates, and the former for plates of high-tensile steel. Plates up to 41 ft. in length and up to 2 in. in thickness can be planed in this machine, and most of the other planers in the shed can deal with plates of the same dimensions.

Leaving the platers' shed at the southern end and returning along the heads of the building berths we reach the rivet store, which is situated in a central position, as shown on the key plan, Fig. 1, on page 367 *ante*. This is a two-storey, steel-framed building, 150 ft. long, 62 ft. wide, and 20 ft. high to the eaves. It has brick dado walls about 6 ft. high, while the remainder of the walls and the roofs are covered with corrugated sheeting. The rivets are stored in bins on the upper floor, and delivered, as required, through steel chutes. A variety of tackle and spares for use on the berths is also stored in this building.

Mention should also be made, while dealing with this part of the yard, of the hydraulic riveting plants which are provided at the heads of the berths, and are used for riveting framing, floor girders, vertical keels, deck girders, coamings, &c., before these details are delivered on to the berths. One of these installations is illustrated in Fig. 134, on page 582, and from this view it will be seen that the hydraulic riveter is suspended from a trolley running on a revolving jib, which is attached to a steel gantry. The work is handled by one of the 10-ton locomotive travelling cranes with 50-ft. jib referred to in our first article, and one of the crane locomotives employed in the yard can be seen in the same illustration.

In the open space in front of the main office building are situated the time-board depositing office, the fire and ambulance station, the frame-punching shed (now in course of erection) and the oil and paint stores, the latter having been kept isolated from all other buildings on account of the inflammable nature of their contents.

(To be continued.)

LITERATURE.

Iron Bacteria. By DAVID ELLIS, D.Sc., Ph.D., F.R.S.E. Royal Technical College, Glasgow. London: Methuen and Co., Limited. [Price 10*s.* 6*d.*]

IN collecting into an ordered and consecutive account his contributions concerning the organisms generally known as iron bacteria, Dr. Ellis has been influenced by two considerations. First, to advance the science of biology by arranging the known facts in such a way that the work of others on the same subject may be facilitated, and also to stimulate further inquiry by indicating the partially-solved problems that need further examination for their full elucidation. The second subject is to appeal to the water engineer and to beg of him to trust and to encourage the work that is done in the laboratory, for the author urges that the effects due to the activities of organisms like the iron bacteria cannot be adequately studied apart from the study of the organisms themselves. Approaching the subject as we do entirely from the practical or engineering side, we may assure Dr. Ellis that he is forcing an open door. Whatever may have been the attitude of the hydraulic engineer in the past, and however indifferent he may have been to the teachings and inductions of pure science, the biologist may confidently rely now on receiving the respectful attention and helpful assistance of the water engineer, in whatever is attempted with the view of forwarding the interests of the profession or the advantage of public welfare.

But the author, who has spent ten years in the study of these minute organisms, who has seen the no less patient researches of other biologists questioned or their deductions refuted, must not be impatient or disappointed if busy men, occupied in other directions, ask for precise information and are unable to follow him in some subtle details or fail to appreciate the ground of controversy and the nicety of the experiments by which certainty is approached. The progress towards accuracy is along a sinuous path. It is not edifying to be told that the reduced discharge of pipes is due to the growth of Gallionella and that Leptothrix, to which the trouble had been attributed, was a comparatively harmless intruder, if he is informed later that the two names apply to different life cycles of one and the same organism. Even the blessed word "pleiomorphic" does not reconcile him to this distinction. Implicit trust on the one hand demands complete knowledge on the other and cannot exist in presence of the contradictions frequently encountered. Let us ask an explanation of those incrustations in iron pipes, beginning as minute dotted projections, growing by accretion and that ultimately coalesce to such an extent that the bore of a pipe may suffer sensible diminution. The late Professor Campbell Brown declared that while some of the nodular incrustations contained iron bacteria, every trace of life was absent from many others, and further he asserted that the iron of the incrustation was in all cases derived from the iron of the pipe. Relying upon the reputation of the distinguished Liverpool Professor, this statement was accepted at its face value. Simultaneously Schorler was demonstrating to another audience, that though the firmer parts of the incrustation might show no traces of Gallionella, yet there were plates in these firmer parts containing each a fragment of that organism. The origin was to be traced to the collection of inorganic matter round an organic particle, and that Gallionella, whether alive or dead, was a focus of attraction for ferric hydroxide and must be held responsible for the incrustation that appeared in supply pipes, culverts, &c. Dr. Ellis holds further that in the light of Schorler's researches it is impossible to accept

Professor Campbell Brown's assertion, that the iron of the incrustation is drawn from the iron of the pipe.

It must be understood that these remarks and examples are offered by way of defence and by no means imply any doubt of the value of the researches, or are intended to belittle the devotion of those who make them. The author has seen fit to resuscitate the exploded myth of the practical man, who entertains "a lingering doubt that science and practice are antagonistic," but it would probably be more exact to say, that in all that the "practical man" does not understand and cannot bring to the test of his experience, he is more than ready to accept the assertions of authority. For that reason, science should not speak with an uncertain voice. We have nothing but admiration for those who have endeavoured to trace the significant features in the life history of these bacteria, and are grateful to them for furnishing methods of treatment, which may minimise their troublesome activities or prevent those calamitous outbreaks which disorganise the ordinary conditions of life.

The term iron-bacteria is a convenient name for a large class of organisms that have the capacity for absorbing iron from the waters in which they live, and storing it in the form of ferric hydroxide on their surfaces. The ochre beds frequently seen in ferruginous pools and streams are generally produced by the collected ferric oxide, and by the dead membranes of these special bacteria. But the name is a misnomer or at least misleading. It suggests that iron is essential to the existence of these organisms, but the contrary is the case. Wherever pure cultures have been successful, it has been proved that these bacteria flourish without iron. Indeed, it may be said that they thrive in spite of the iron rather than in consequence of it. Further, if manganese is easier to come by than iron, the indiscriminating bacteria will absorb it quite as greedily as the iron itself. It would be as appropriate to call these forms manganese-bacteria, as iron-bacteria. The term is probably due to Cohn, who, in the early days of the study of this minute living matter, taught that the association of bacteria with iron was analogous to that of silicon with diatoms. Just as these latter absorb silicon from the water to build up their enclosing shells, he suggested, that by some process of selection, the protoplasm of these organisms assimilated ferruginous salts from the other constituents of the water and utilised them to strengthen their membranes. Though the theory or suggestion has fallen into disrepute, the name has remained, and probably will remain, for though the protoplasm and iron do not react in the manner Cohn suggested, there is some peculiar association between the mineral and the organism which remains unexplained. Professor Campbell Brown pointed out that iron bacteria did not thrive, except in waters containing an appreciable amount of iron in solution, in combination with organic matter of an acid character, and from that date more and more importance has been attached to the organic molecule in the water. Following up the clue the conviction has gained ground, that the protoplasmic molecule of the bacteria enters into combination with the organic molecule in the water, and according to the nature of the mineral salt attached to the organic molecule, the character of the secretion and collection will be determined.

But this does not explain why other bacteria, equally saprophytic organisms, living under the same circumstances and possessing apparently the same apparatus do not coat themselves with ferric oxide. Why have these so-called iron bacteria specialised in the collection of old iron? They seem to operate like minute magnets, and Dr. Ellis suggests as a working hypothesis, if we correctly understand him, that iron bacteria and other iron-collecting organisms, as some protozoa and algæ, possess a chemiotactic affinity for iron compounds. Those colourless organisms that are endowed with this affinity, select, in preference, the organic molecules that contain iron in combination, and the effect of this selective faculty is exhibited by the reddish-brown colour characteristic of ferric hydroxide.

This explanation, however satisfactory in some aspects, fails to account for the amazing fecundity, and rapidity of collection displayed by Crenothrix, among others, whose multiplication may be so rapid that in a short time its operations become visible to the naked eye, the ordinary colour of large masses of water changing to reddish-brown. The Cheltenham outbreak in 1896 furnishes a well-known instance. First detected in March, in isolated cases, by April the whole reservoir supplying the town had become brownish red, in May, the climax was reached and the reservoir resembled a great horse pond. About the middle of the month the annoyance diminished and by the middle of June, normal conditions were restored. We may admit that the chief factor in determining the growth of Crenothrix is the amount and nature of the organic matter in solution in the water, but the man in the street fails to understand the possibility of any sudden change in the environment that would explain the abnormal conditions present in 1896 to distinguish it from many others. Either a violent outbreak is observed or none at all, and since the results are so startlingly different in different years we ought to find a proportionate difference in the causes. A suggestion is made that the increase of Crenothrix polyspora was more rapid than the organic matter in the water was able to support, and that relief was due to the excessive population dying out from inanition, but this seems hardly satisfactory, because it is evident from the growth of the pest throughout April that the nutrition in the water could have sustained a larger number than are ordinarily present.

The study of the development, the nutriment and the activities of these bacteria has indicated the measures best calculated to remove or to diminish the inconvenience they occasion, whether physiological or mechanical. The bacteria are not of the nature of pathological microbes, they yield no toxic effects and, as far as known, are not in any way injurious to public health. On this account, their removal from potable water, if it were practicable is not to be recommended, and as a matter of fact it could not be accomplished without annihilating all organic life in the water. The more philosophical process consists in keeping their numbers within bounds, by depriving the organisms of their food, or of so altering its composition that it is useless to them. This result can be accomplished in various ways, most effectively by increased aeration of the water. By encouraging the growth of green plants which liberate oxygen on exposure to light much may be done, but dead and decaying vegetable matter arising from this source will add to the food supplies. Means should be adopted for giving full play to the nitrifying bacteria, by filtration especially, for the work of these latter is to oxidise the organic matter into compounds from which the iron bacteria can derive no sustenance. Another line of treatment that can be equally effectual is to render the water alkaline, where the iron bacteria congregate. The adoption of such means as those with which the water engineer is familiar would certainly tend to the removal of some, and probably of all, kinds, but the Gallionella ferruginea that produces the objectionable slimy streamers, not having been studied in an artificial medium may successfully resist this treatment.

From the mechanical point of view the last-named bacteria deserves drastic treatment, for it is certainly a causative organism in the production of the slimy streamers, that by their collection diminish the flow of water in pipes and probably also in the formation of the destructive incrustations or nodular excrescences on the inside of conduit pipes where they are in contact with water. To what extent the organisms contribute, and whether the iron is obtained from the pipes or from the water, and what is the precise manner of growth in these incrustations, are still unsolved problems. The threads of slime are really colonies composed of a large number of organisms, which, starting from a single growing point as a focus of attraction, absorb the iron in their mucillaginous sheaths, and by gradual accretion thrust out a thin line of matter into the water, one end being fixed to the pipe. These tiny threads grow in volume, and adhere till they finally become visible to the naked eye, and sufficiently numerous to reduce sensibly the bore of the pipe.

The origin of the tubercular incrustations is more difficult to explain, and it must be admitted that biologists disagree on some important points. There can be no doubt but that tubercular growth will take place in the complete absence of iron bacteria or any other organisms. But the biologists are unwilling to record a full verdict of acquital, and they insist or at least some do, that the iron bacteria play a part, if a subordinate one, in expediting the change which takes place inside the tubercle, by secreting carbonic acid. But iron incrustations may be found on non-ferruginous substances, and consequently under circumstances in which the whole of the iron must be derived from the water. These irregular rust layers showing large and small swellings may have been formed entirely by threads of Gallionella, but our author will go no further than admit that the organism is responsible for the accumulation of ferric hydroxide on the walls of the piping. With regard to the spongy disease of cast-iron, it is admitted that the iron bacteria play no part in its production.

The Dyeing Industry; being a Third Edition of "Dyeing in Germany and America." By S. H. Higgins, M.Sc., Dyers' Company Gold Medallist for Research, Technical Chemist and Works Manager. Manchester University Press; London: Longmans, Green and Co. [Price 8s. 6d. net.]

SOME fifteen years ago, under the auspices of the Manchester University, the author of this work visited the parts of Germany and the United States in which dyeing and allied industries were most actively prosecuted, with the view of examining the conditions under which the trade was conducted. The results of his investigation were embodied in a Report published under the title "Dyeing in Germany and England." Into that report he has incorporated the results of his observations made in England, and this additon has necessitated the alteration of the title to the form it now bears. Much of the original material has been allowed to stand, but as the author has had no opportunity of continuing the inquiry on the Continent and in America, it is easy to think that the present conditions bear little relation to those which he saw and described. In Germany, the war and its aftermath have paralysed the energy and presumably destroyed much of the organisation that was so conspicuous in the great colour-producing and dyeing centres, while the nascent and inexperienced manufactories of the United States have developed a giant strength. Armed with abundant capital and buttressed by protective legislation, the energy developed threatens not only to be sufficient to satisfy home demands, but to be a competitor in the world trade that Germany has so long overshadowed or monopolised. There are consequently two opposing positions which might be vividly and directly contrasted with very instructive results, but the utilisation of the work published in previous editions prevents the antithesis being presented in its most attractive and salient form.

A contrast of a different kind that is not emphasised, but runs as an undercurrent throughout, arises from the difference paid in England and Germany to the importance of scientific acquirement and training, and the part played by pure science in promoting and extending the industry. The assertion has been made, probably with sincerity and conviction in the first place, but repeated and exaggerated without much inside knowledge later, that the pre-eminence gained by Germans in colour manufacture and associated industries is due to the encouragement given to special training of the chemist, both in the laboratory and in the works. As a corollary our own want of success and failure in competition is attributed to the studied neglect of properly qualified assistants. This view is not held by the author, or at least not in the assertive and unquestioning way to which some have given it expression. He did not perceive that boasted and marked superiority of the German organisation of which we have heard so much, but on the other hand it must be remembered, that he was himself a trained chemist, of equal calibre to those he met. He was not likely to perceive a contrast which might have been sufficiently patent to one, who was less efficiently

qualified. We certainly should be grateful to the author for upholding the sufficiency of English methods, and that when he went into the house of Rimmon he refused to bow the knee to the august divinity. To enter a little into details the author tells us that in bleaching operations, "latterly chemistry has been applied to the process, but it is remarkable that science has caused little change in the old process." And again, "it must be remembered that a knowledge of chemistry cannot replace experience in the bleaching industry. There are many operations in practice which the chemist cannot explain and he must proceed cautiously, while paying due regard to the teaching of experience, instead of underrating the value of that experience." Concerning the dyeing industry, this expert who writes as a works chemist and manager and has had large experience in the Manchester College of Technology states, that he "did not find the Germans employed more scientific skill in dye works than we did. In fact, the wages paid in the dye works are too small to attract the best skill." In a third branch, that of colour manufacture, the author while writing appreciatively of the German methods, but not in the fulsome strain to which we are accustomed from those who wish to magnify our shortcomings, Mr. Higgins says "the excellence of the colour works is the cause of much talk about the superiority of the German methods and systematic German chemical education . . . It is the author's firm belief, that it is because of the development and the organisation of these colour works that we hear so much of the scientific German, who is busy applying science to industry."

In the aniline colour industry, in which new processes may be invented or new colours discovered, the conditions are different. Here it is admitted that research work has achieved some notable and valuable results. But the author hints, that the game is hardly worth the candle. Hundreds of research chemists—some of the large firms employ a small army—are trying the effects of new grouping, and in a variety of more or less stereotyped methods preparing new organic compounds. The author makes the obvious comment, that if a large number of men are employed on so-called original work, a certain number of discoveries will be made, "but when one considers that many of the most profitable products of these works have been discovered outside the works laboratory, it is manifest that each one of the research chemists cannot have achieved many distinct triumphs." This remark is pertinent, for it is intimated that the remuneration of the research chemists is small, that the custom is for the patents to be taken out by the firm, and, if successful, the inventor gets a share of the profits. On the surface this payment by results does not appear to be satisfactory, for we have learnt that the number of successful patents is few. The fallacies of hope and the bitterness of disappointment would seem to be the only reward of the greater number who tempt fortune. Such unsubstantial returns should not be without some weight in deciding a problem which is said to be hindering applications from organic chemists for admission into the new colour and dye laboratories set up in this country. Applicants, it is understood, resent the proposal that they should relinquish any rights or interests that may attach to patents resulting from investigations conducted in the laboratory, and since every one naturally expects that he will be a fortunate inventor, this proposed clause in the agreements acts as a deterrent. If Mr. Higgins' practical remark could be realised, that invention in this direction is a lottery of few prizes and many blanks, it would diminish the objections that have been raised to the proposed restriction on eager aspirants. The prospective value of a new colour must be small. It appears that some 700 have been patented at different times, and many of these can be very closely imitated by mixing two or more already in the market. Large quantities of the better colours are necessary, and should be produced on a large scale. This no doubt is the direction in which Americans will work. To produce in bulk appeals to the American temperament, and there is no doubt that such fundamental dye stuffs will be exported in large quantities.

The whole question of patents is difficult, and we cannot say that we find the author's guidance always satisfactory or even consistent. From what has just been said we might conclude that patents have little pecuniary value, and judging from the number granted to the number actually worked, the hope of profit must frequently prove delusive to the patentee. But it is further urged that by granting patents to foreigners we have prevented home developments, and foreigners coming to this country have been granted monopolies their own refused them. But if the foreigner is granted something that is useless he is not much benefited. The Germans, we are told, patent everything, but only work those that are considered valuable. These, however, have but a short life and the patent owner has to make his profit while the object of his patent is a novelty, for though in its early days it commands a high price, it is soon displaced by a rival. The author urges, with a reserve against the possibility of evasion, that to make the inventor work his patent in the country in which it is taken out is the best direction for a needed reform. We may admit that he has on his side the practice obtaining in all European countries, and though in America this safeguard has not been adopted, it is suggested that the high tariff prevailing produces a similar effect.

The problem is a thorny one extending far beyond the colour trade, though here there are circumstances which give it a peculiar significance. The same may be said of the much-discussed subject of protection, which divides public opinion hopelessly. Writing in 1907, when the Manchester School of Free Trade decided fiscal policy, the author wrote, "Protection would have little effect in keeping out the German dyestuffs and the cost of production of our dyed goods would only thereby be raised." Writing later, however, after the war, when an examination of fiscal policy and ancient creeds was compulsory, he adds, that "Free traders have always admitted that protection is sometimes of advantage in developing new industries" and the demon of protection is no longer exorcised with the vehemence to which we have been accustomed. In describing the progress of British Dyes, Limited, whose development he believes will prove a great success, the unwelcome formula is finally accepted by the admission that "Certain it is that some protection will have to be provided for the new enterprise." It is not quite clear in some other passages whether Mr. Higgins is stating his own opinion, or quoting with approval the dicta of representative bodies, but so far as America is concerned, apparently the policy is laid down as an axiom that "to protect the textile industries using chemicals and dye stuffs and make them independent of foreign nations, the nation must bear the burden incident to such expansion." The burden takes the form of a high tariff, which it is assumed the trade could bear easily.

The problem is far from solved, but it is interesting and desirable to have the deliberate opinion of one, who, after having had opportunities for studying the operations of manufacture and the working of a settled policy in other countries, is actively engaged in the effort to re-establish and to maintain a decayed industry that "English brains created, English enterprise developed, and English legislative folly has caused to decline." Undoubtedly in the race for supremacy we have much leeway to make up, and it may be that we are too heavily handicapped. The factors that make for success have been sadly neglected, and it will be only by great exertion and sacrifice that we may hope to share in the trade that Germany has studiously fostered by scientific training, and assiduously cultivated by industrial enterprise. Germany possesses a magnificent advantage in her well-organised colour factories, her well-equipped research laboratories, her libraries and her accumulated experience, but more than any of these is the recognition of the benefit to be derived from the close alliance of science with industry, the provision of adequate technical education, and the assistance of a disciplined service. The author enumerates many other favourable conditions the Germans enjoy, but to examine these thoroughly and to weigh them accurately is not necessarily to be daunted or dispirited by the heaviness of the task before us. The author renders a service in putting the case before the public, in considering all contingencies with prudence but without alarm, and in bidding us have hope and confidence. The synthetic dyes do not include the whole range of chemical manufacture. Our heavy chemical industry is of great value and importance, and can hold its own, if perseverance, courage and enterprise are forthcoming in the future, as they have been in the past.

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Wireless Transmission of Photographs. By MARCUS J. MARTIN. Second edition, revised and enlarged, 1919. London: The Wireless Press, Limited. [Price 5*s.*]

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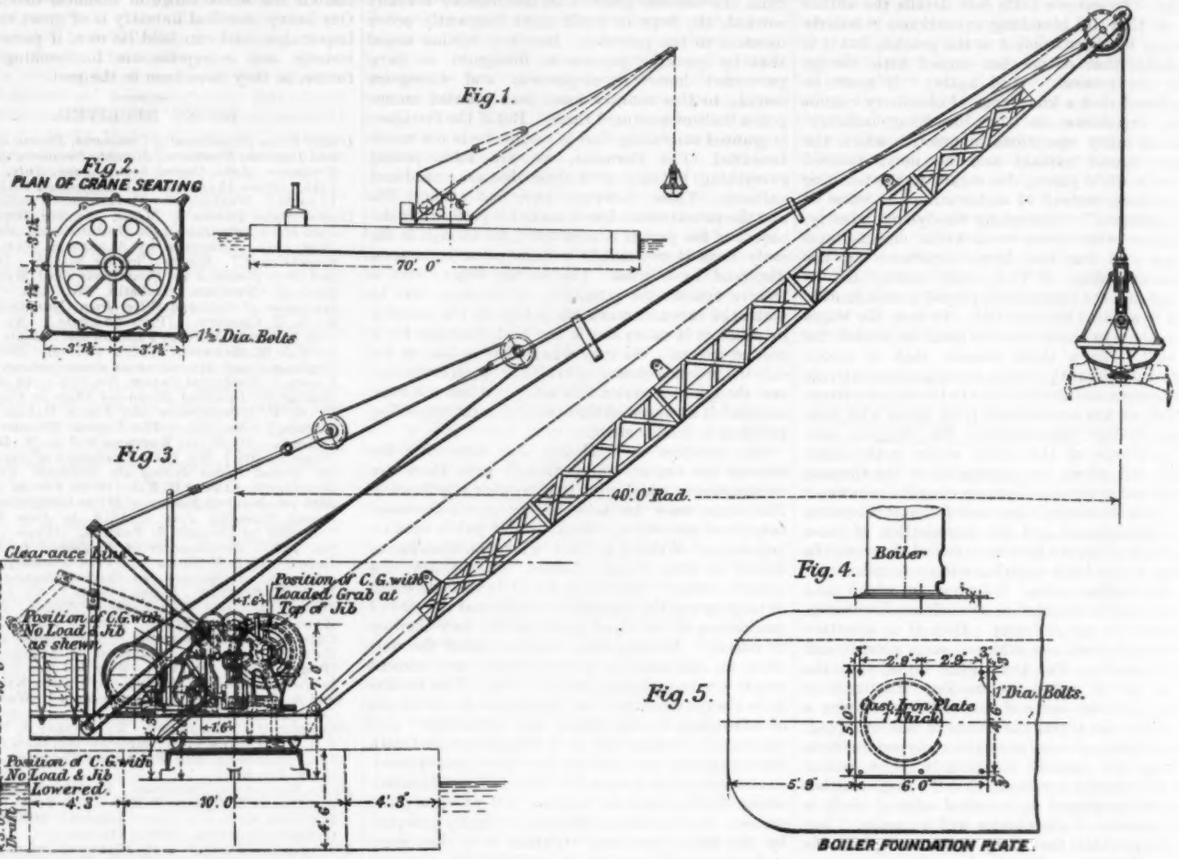
LIVERPOOL CORPORATION TRAMWAYS.—The annual report of the general manager of the Liverpool Corporation Tramways for the year ended December 31, 1919, shows a total expenditure of 1,028,943*l.* 11*s.* 5*d.* and a total income of 1,190,526*l.* 7*s.* 8*d.* The number of passengers carried during the year was 208,251,496, the mileage amounting to 13,184,277. The average earnings for the year were 21·46*d.* per car-mile, an increase of 2·55*d.* over the figure for 1918. The length of track operated was 127 miles.

GRAB DREDGING PLANT FOR THE FEN DISTRICT.

DESIGNED BY MR. E. G. CROCKER, CONSULTING ENGINEER TO THE SOUTH LEVEL DRAINAGE AND NAVIGATION COMMISSION.



THE grab dredger, illustrated on the present and opposite pages, has recently been constructed for the South Level Commission, Ely, and put to work on the River Ouse. The plant possesses a number of interesting features, the vessel itself, designed and constructed by Mr. E. G. Crocker, consulting engineer to the Commission, being of reinforced concrete.

The vessel consists of three reinforced concrete pontoons having an overall length of 72 ft., an overall beam of 22 ft. and a draught, when fully loaded, of 3 ft. 9 in. The side pontoons are of 5-ft. beam, connected to the central pontoon by four 9-in. by 4-in. rolled steel joists, fitted with the necessary bearing plates and secured by 1¼ in. bolts, and are readily detachable so as to allow of the passage of the vessel through locks, the central pontoon then carrying the complete plant on a draught of 4 ft. The vessel is fitted with a double-cylinder steam winch, having six drums, forward and with the necessary bollards and fairleads to enable the vessel to be manœuvred by the means of the anchors and wire rope cables without hand labour. A cabin has been fitted out to provide living accommodation for the crew of two men, and movable shelters (not shown in photographs) are provided over both the crane and boiler to protect the workmen from the weather.

The order for this plant was placed in May, 1916, but owing to the war the machinery was not delivered until July, 1919, the reinforced concrete pontoons were, however, constructed in 1916, and have been afloat since early in 1917. The decision to build the vessel in reinforced concrete, was made mainly on the question of cost, the quotation for 50-ft. steel pontoons being 1,500*l.*, whereas the actual cost of the concrete pontoons was 839*l.* 9*s.* 9*d.* including the increase in the price of the connecting girders, bollards, &c., from 1916 to 1919, amounting to 65*l.* The concrete is composed of 1 part of Portland cement, 1½ part of sand and 2½ parts of broken granite measured by volume, these proportions giving a concrete which for a thickness of 2 in. is impervious under the conditions to which the vessel is subject, the pontoons being absolutely dry inside, provided the mixing and depositing is carried out in a proper manner.

The dredging equipment comprises a steam grab, designed and manufactured by Priestman Brothers, Limited, of Holderness Foundry, Hull. To enable the

FIG. 6.

GRAB DREDGING PLANT FOR THE FEN DISTRICT.

DESIGNED BY MR. E. G. CROCKER, CONSULTING ENGINEER TO THE SOUTH LEVEL DRAINAGE AND NAVIGATION COMMISSION.

Fig.7. LONGITUDINAL SECTION ON LINE B.B.

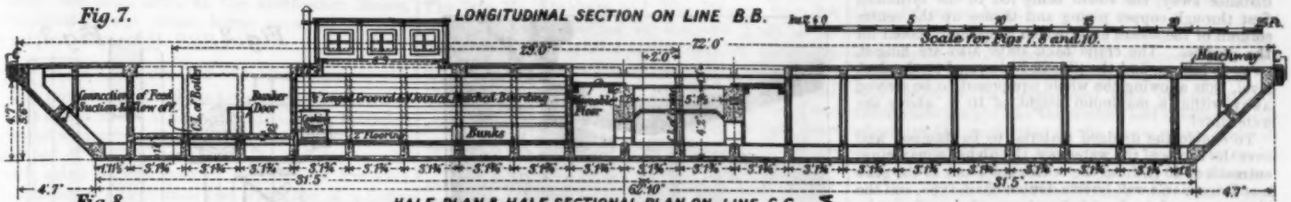


Fig.8. HALF PLAN & HALF SECTIONAL PLAN ON LINE C.C.

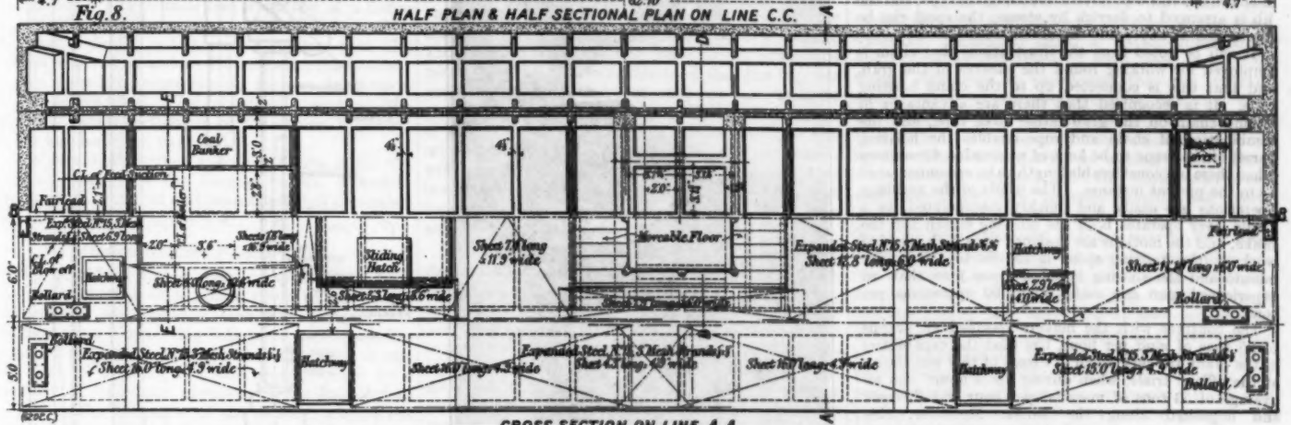


Fig.9. CROSS SECTION ON LINE A.A.

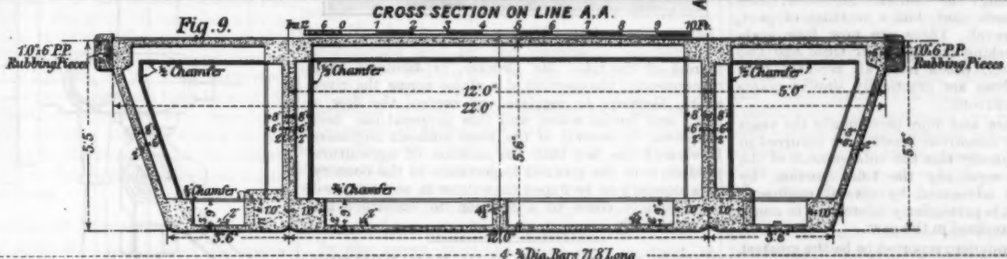


Fig.10.

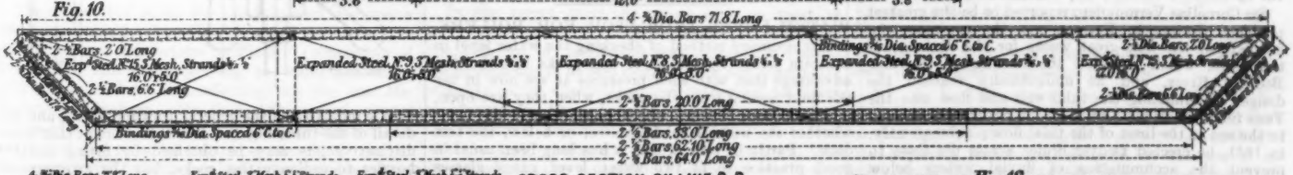

4-¾Dia. Bars 71'8 Long
Expanded Steel, N°15, 5 Mesh, Strands ¼"x⅛
Expanded Steel, N°8, 5 Mesh, Strands ¼"x⅛
Bindings ¾"Dia. Spaced 6' C. to C.
2-½ Bars, 20'0 Long
2-½ Bars, 53'0 Long
2-½ Bars, 62'10 Long
2-½ Bars, 64'0 Long

Fig.11.

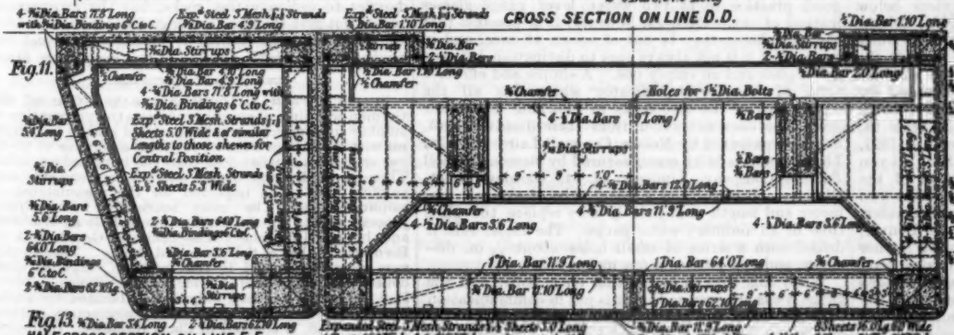

CROSS SECTION ON LINE D.D.
4-¾Dia. Bars 71'8 Long with ¾Dia. Bindings 6' C. to C.
Exp.d Steel, 5 Mesh, Strands ¼"x⅛ Sheets 5'0" Wide & of similar Lengths to those shewn for Central Position.
Exp.d Steel, 5 Mesh, Strands ¼"x⅛ Sheets 5'3" Wide
Holes for 1⅛ Dia. Bolts
4-¼Dia. Bars 12'0 Long
4-¼Dia. Bars 11'9 Long
4-¼Dia. Bars 3'6 Long
¾Dia. Bar 11'9 Long
¾Dia. Bar 11'10 Long
¾Dia. Bar 64'0 Long

Fig.12.

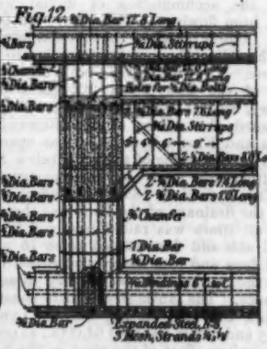
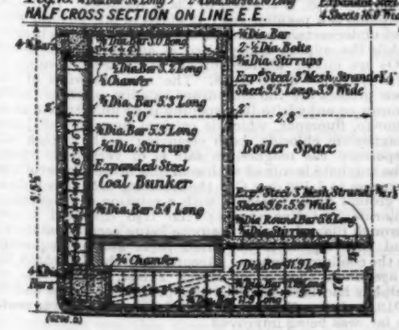


Fig.13. HALF CROSS SECTION ON LINE E.E.


¾Dia. Bar 3'4 Long
2-½Dia. Bolts
¾Dia. Stirrups
Exp.d Steel, 5 Mesh, Strands ¼"x⅛ Sheet 9'5 Long 3'9 Wide
Boiler Space
Expanded Steel
Coal Bunker
¾Dia. Bar 5'4 Long
Exp.d Steel, 5 Mesh, Strands ¼"x⅛ Sheets 5'6 & 5'6 Wide
¾Dia. Round Bar 6'6 Long
¾Dia. Stirrups
¾ Chamfer
1"Dia. Bar 11'9 Long

ELEVATION OF HALF LONGITUDINAL DECK-BEAM.

Fig.14.

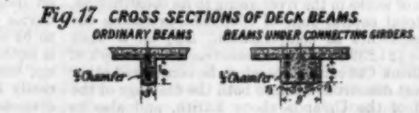
¾Dia. Bar 13'0 Long
¾Dia. Stirrups
Exp.d Steel, 5 Mesh, Strands ¼"x⅛ Sheet 4'5 Long 1'6 Wide
Offset to carry Movable Floor around Crane
¾Dia. Bar 13'0 Long
¾Dia. Bar 12'9 Long

CROSS SECTION OF FLOOR BEAMS AT BOW & STERN.

Fig.16.

Fig.15. ELEVATION OF HALF DECK BEAMS.

Fig.17. CROSS SECTIONS OF DECK BEAMS.



Scale for Figs 11 to 17.

plant to pass under low bridges the dredger is of the separate boiler type; that is to say, the boiler is not mounted on the footplate of the steam grab, but is placed on the floor in the after part of the vessel some distance away, the steam being led to the cylinders, first through copper piping and thence up the centre column of the steam grab, which is specially bored for the purpose. The crane back stays also are hinged, so as to fall up, and the jib can be lowered to the deck level, thus allowing the whole equipment to be stowed away within a maximum height of 10 ft. above the water-level.

To enable the dredged material to be dumped well over the banks of the waterway, the jib has a maximum outreach of 40 ft. from the centre post, and as the grab is of Priestman's well-known double-chain type, and the jib is arranged to derrick by steam, the spoil can be discharged at any point the driver wishes.

It will be noted from the illustrations that chain is employed for working round the sheaves of the grab, and that this is connected up to the crane hoisting rope. It is recognised that there are advantages in having chain on the grab rather than rope, and the combination of chain and rope enables the hoisting barrel of the crane to be kept of reasonable dimensions when there is a considerable length to be accommodated as in the present instance. The whole of the grabbing operations are easily and quickly manipulated, as a single lever operates both the hoisting clutch and the brake, and the motions are designed for a high speed of working (the hoisting speed is 130 ft. to 150 ft. per minute and the slewing speed 3 r.p.m.) so that an experienced man can make 50 to 60 operations per hour.

The contract with the makers specified an output of 25 tons of mud per hour, but that the capabilities of the plant are very much in excess of this was shown at the official trials, when during the 3 hours' run an average of 53 tons of material per hour was dredged and deposited along the banks. Moreover, this material was not soft mud, but a mixture of peat, clay, shale and gravel. There are now four grab-dredging plants working on the River Ouse and two in an adjoining level, which have all recently been supplied; five of these are practically similar plants having open steel pontoons.

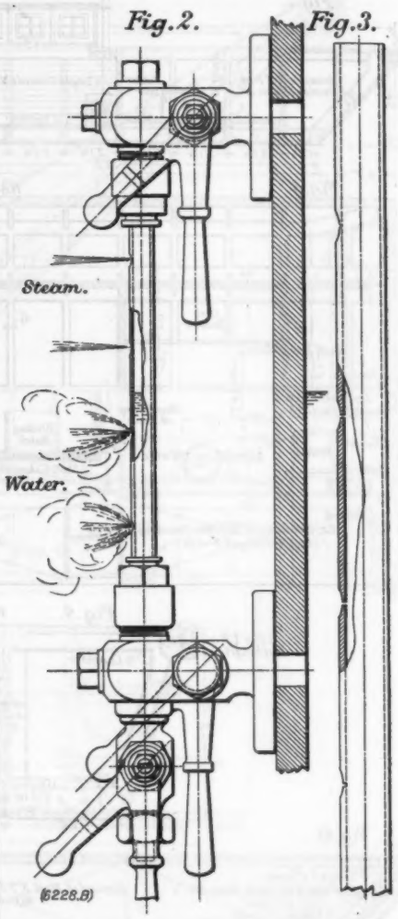
During recent years, and more particularly the years 1915 to 1919, many disastrous floods have occurred in the Fens, and to remedy this the enlargement of the River Ouse, more especially the tidal portion, by dredging, has been advocated by several engineers, and in this respect it is particularly interesting to study the effect of works executed in the past.

Sir Cornelius Vermuyden, reported to be the greatest practical drainer in Europe, was the engineer who carried out the first great works for the drainage of the Fens, which included the cutting of the new Bedford River, and he undoubtedly realised the danger of admitting the tidal ebb and flow into the Fens for he took his New Bedford River only so near to the sea as the limit of the tidal flow; subsequently, in 1651, he erected Denver Sluice across the Ouse to prevent the accumulation of fluvial waters below Denver, from flowing up that river. In 1664, Colonel William Dodson proposed the erection of a great sluice across the River Ouse at St. Germans to exclude the tidal flow. The next great work executed was the cutting of the Eau Brink Cut (first proposed by Kinderley, and carried out by John Rennie), which straightened the course of the River between St. Germans and King's Lynn, and was opened in 1821, a further straightening of the river below King's Lynn being afterwards made by the construction of the Marsh Cut, opened in 1852. The effect of these two Cuts on the drainage of the Fens was that high water-level at all times was raised nearly 2 ft. at Denver, the tidal ebb and flow carried some 16 miles further into the Fens and low water-level raised during flood periods, the works thus being very disadvantageous to drainage. The authority which constructed the Eau Brink Cut had to pay to the Lynn Harbour Authority and others a sum of 64,000*l.*, as compensation for the injurious effect of the work on the harbour, and an annual payment of 750*l.* from the year 1832 onwards whilst the tolls produced such amount, and the amount of the tolls until 1893. Also further sums amounting to 88,455*l.* were paid in compensation to other authorities for the effect of the construction of the Cut on works above it, and a sum of 46,410*l.* was expended on the execution of works in the river owing to its construction, being a total capital sum of 198,865*l.*, exclusding the annual payments as compensation, &c., on a work which cost 221,239*l.* 16*s.* 6*d.* to construct. The work of the Eau Brink Cut cannot therefore be considered other than a most disastrous work to both the drainage of the Fens and of the Uplands above Earith, and also to navigation, and should be a warning against the execution of any works of a like nature in the River Ouse and to the deepening and widening of the river by dredging or other means which will facilitate the ingress of the tide. Mr. Crocker, in January, 1916, recommended the erection of a sluice across the river, at St. Germans to regulate and control the flow of tidal and fluvial water, and this proposal has been supported by several of the most eminent engineers. In view of the fact that the increase of agricultural produce is of the greatest importance to the country, it is sincerely to be hoped that those in authority will very quickly come to a decision to construct this essential work.

BRASS TUBE WATER GAUGE.

CONSTRUCTED BY MESSRS. BROMELL PATENTS COMPANY, LTD., GLASGOW.

FIG. 1.



This is indicated in the general drawing, Fig. 2, and the detail of the tube, Fig. 3. It will be evident that these distinctive jets may be obtained by fitting suitable nozzles to ordinary test cocks, but the arrangement would not give the close reading of water level which is obtained with the indicator, unless an unusual and probably undesirable number of test cocks were fitted.

WATER LEVEL INDICATOR FOR BOILERS.

THE ordinary method of checking the water level in a steam boiler by means of test cocks has the disadvantage that with such pressures as are now in use the fluid issuing from the cocks, when they are open, is in the form of a jet which is practically the same whether the water level be above, or below, the test cock. Partly in view of this it has long been usual in good practice to fit two water-level gauge glasses instead of one. Even so, however, it is possible that the two glasses may be out of action at once, and in some cases it is not always easy to distinguish between a full glass and an empty one. A simple and effective form of water-level indicator which has all the advantages of the test cocks in checking the water level, but does not suffer from their disadvantages, has been patented by Messrs. Cammell Laird and Co., Limited, and is being manufactured by Messrs. Bromell Patents Company, Limited, of 64, Darnley-street, Glasgow. It consists of a metal tube of external diameter and length such that it may replace the glass tube in an ordinary water gauge. The metal tube is drilled with a series of small holes about $\frac{1}{16}$ in. diameter, and at a pitch of a few inches apart.

When this tube is in position on a boiler and the gauge cocks are open so that it is put in communication with the water and steam spaces, it is found that the jets which issue from the holes which are below the water level are very distinct in character from those which issue from the holes above the water level. The steam jets issuing above the water level are barely visible and have a very small angle of divergence, while the jets below the water level are in the nature of a distinct white, cloudy spray, and have a wide angle of divergence. This is illustrated in Fig. 1, which shows an indicator in operation. It will be clear that this device enables a very close reading of the water level to be obtained with ease and certainty, and that there is nothing in it to go wrong. A hole may be stopped up, but if this happens it is at once evident and may easily be cleared. With the size of holes used, $\frac{1}{16}$ in. diameter, this minor trouble is not very likely to occur. It is found that the best contrast between the jets is obtained when the length of the jet passage is equal to its diameter, and to obtain this proportion a flat is filed on the tube at the point where the hole is drilled.

SULPHUR FROM CALCIUM SULPHATE.—One of the German war-time chemical processes, the preparation of sulphur from calcium sulphate, is said still to be carried on with advantage because it yields a sulphur of 99·95 per cent. at a smaller cost than the imported material. There is hardly any native sulphur in Germany, and sulphur had to be imported for the manufacture of sulphuric acid. The most successful new sulphur process worked by the Sulfur Gesellschaft at Walbeck, and by the Deutsche Claus- Schwefel Gesellschaft at Bernburg, is that of Schaffner and Helbig. The primary new reaction utilised is that calcium sulphide, when boiled with magnesium chloride, yields hydrogen sulphide H_2S, which so far had only been liberated by acids. The second reaction, the isolation of elementary sulphur from the H_2S, is effected in Claus furnaces. Hydrogen sulphide is a peculiar gas; it burns in air, yielding SO_2, but under certain conditions only the hydrogen is burned, while the sulphur is deposited as such; when H_2S and SO_2 are mixed, all the sulphur is gained according to $H_2S + SO_2 = 3H_2O + 2S$. The raw materials of the new process are the anhydrous calcium sulphate $CaSO_4$ known as anhydrite [the spelling is as unfortunate as in fluorite, fluorspar, which is calcium fluoride CaF_2] and magnesium chloride, both occurring in the potash salt deposits; the magnesium salt is of very little value. The sulphate is mixed with coal and heated in revolving furnaces to 1,100 deg. C.; the resulting calcium sulphide is ground up and treated with a solution of magnesium chloride and live steam; the H_2S liberated passes through Claus furnaces (bauxite being used as catalyst), and the sulphur is deposited there and subsequently in the cooling chambers. According to the *Zeitschrift für Angewandte Chemie*, of March 2 last, 23,000 tons of sulphur had been made by this process up to the end of 1919, and the efficiency of the sulphur yield, 60 per cent. so far, was being improved.

THE INSTITUTION OF MECHANICAL ENGINEERS.

A MEETING of the above Institution was held on Friday, the 23rd inst., at the Institution House, Westminster, the chair being occupied by the President, Captain H. Riall Sankey.

THE LATE MR. WILSON WORSDELL.

The president opened the proceedings by referring to the death of Mr. Wilson Worsdell. Mr. Worsdell became a member of the Institution in 1894 and a Member of Council in 1909. He had for several years acted as chairman of the General Purposes Committee. The council had approved of a letter of condolence being sent to Mrs. Worsdell. Mr. Worsdell's death had been so sudden that the council received no notice of it until after the funeral; it was therefore impracticable for the Institution to be represented. (An obituary notice of Mr. Worsdell, with particulars of his career, appeared in our last issue, on page 553.)

The president further announced that to fill the vacancy caused by the decease of Mr. Worsdell, Mr. L. St. L. Pendred had been appointed a member of council for the current year.

JUNIOR GRADE OF GRADUATES.

The president stated that, in connection with the establishment of a junior grade of graduates, the council had decided that any matriculated student of an engineering college or an engineering pupil or apprentice not less than 16 years of age nor over 19 years of age, and recommended by a member or associate member of the Institution, might, at the discretion of the council, receive the Journal annually at a charge of 1*l.*, together with a ticket entitling him to attend the meetings of the Institution. The question had been raised, during the discussion of the by-laws, by Mr. Moss, supported by Mr. Evans, and a committee had been formed, of which the two gentlemen named were members. It was ultimately concluded that all wishes in the matter would be met by the resolution of the council above indicated. The decision of the council would at once come into force.

HARDENING OF SCREW GAUGES.

The paper set down for reading and discussion was one entitled "The Hardening of Screw Gauges with the least Distortion in Pitch" (consisting of two parts, the first referring to water-hardening and the second to oil-hardening) by the late Mr. Wilfrid J. Lineham. Mr. G. T. White, had revised the papers, but before reading them in abstract, he expressed his personal regret at the death of Mr. Lineham, with whom he had been associated as chief assistant. Mr. Lineham had struggled long to find an effective system of producing hardened steel screw gauges in quantity. On the achievement of success his health had completely broken down. The speaker had accepted as a duty the request of the Council of the Institution that he should revise the paper in accordance with certain criticisms of the examiners; in doing so he had added nothing of his own. Mr. White then read his abstract. Before passing on we would like to say we have never listened to a clearer and more able abstract of any paper read before the Institution. We reprint the papers on page 593 of this issue.

The president then opened the discussion. He referred to the fact that the council had just appointed a committee to deal with discussions, to "stage manage" them, so to speak. The committee would consist of the speaker, *ex officio*, Mr. Patchell, Mr. Pendred and Mr. Marshall, who was not a Member of Council. It was hoped, by communicating with experts on particular subjects coming up for discussion to induce them to speak on some definite point, to the great advantage of such discussions. The paper before the meeting embraced a most important detail, which, a few years ago, would have been regarded as superfluous. He would call attention to the curves shown in Figs. 7 to 14 of the paper, as illustrating the power residing in curves. Figs. 7 to 12 did not indicate the existence of any law whatever, but the law became immediately obvious in Fig. 13. It might be less obvious in Fig. 23, but the point he wished to emphasise was this, that a method in which the plotted results were superposed, enabled laws in Nature to be discovered and determined.

Colonel R. E. Crompton referred to the painful duty of criticising adversely a deceased author. The late Mr. Lineham had, like Edison, been too self-contained. Had he, for instance, gone to the Standards Office for information on gauge-hardening, he would there have learnt what had been done by the late Mr. Clements, of the Birmingham Small Arms Company, and Sir Frederick Donaldson, and also by the speaker some fifteen or sixteen years ago, and would have found that almost all his experiments had been anticipated. The investigators named had reached the same class of results, and had found that, for gauge purposes only, the case-hardening of mild steel would do in a fashion. The object, however, had been to do something more. It was always understood that the tap was master of the situation; of what use were accurate gauges without accurate taps? The determination of something good enough to harden the taps and minimise distortion had formed part of the speaker's work for sixteen years, and it was only now that investigation was arriving, in the matter of case-hardening of modern steels, at what had been achieved with mild steel.

The formation of the Committee of the British Association to deal with the question of the interchange of screws was almost the last thing undertaken by Sir Joseph Whitworth, and some twenty-five years ago the speaker had met Sir Joseph on that committee. It had then been shown that the laying down of screws on paper, their shape, pitches, &c., was not sufficient; some system of gauging was required, and hence the attempt to make screw gauges. That attempt, due to the work of men like the author had been successful in producing so-called screw-gauges used for the purpose of passing the tests of the N.P.L. and to put into the hands of inspectors, but which were later found to be practically useless. Such gauges had had to be superseded by optical methods, and unless gigantic tolerances were given, the result of passing any considerable amount of work through the gauges was, owing to heavy wear and tear and distortion of the gauges, such that the gauge fallacy began to be exposed towards the close of the war.

In the paper itself the errors were so great as to do positive harm if uncriticised. For instance, the first law of hardening was incorrectly stated. All carbon alloys at 900 deg. C. were non-magnetic; whereas, after quenching and returning to lower temperatures, they became magnetic. Therefore the author's assertion that "sudden quenching after heating retains the steel in the condition that prevailed at the quenching temperatures"—i.e., non-magnetic and soft—would, if literally interpreted, be the reverse of what it had been intended to say. The metallurgists of to-day agreed that just above the top absorption point the carbon alloys consisted of nothing but solid solution. In a rather large piece, weighing more than 2 lb.—a big gauge or tap—by quenching from just above the top absorption the solid solution would be decomposed into troostite, which, of course, was not the condition at the quenching temperature.

The author's second law of hardening was, as defined, dangerously misleading, for although "quenching while crossing an arrest or recalescence point, produces the least amount of distortion" it was absolutely impossible so to produce hardness; therefore the quenching temperatures needed to be somewhat above the recalescence point, as, later, appeared by the paper. The author had, further, stated that the Wild-Barfield process depended on the change in magnetic properties of wrought iron or steel, and was a success; that was perfectly true. It should, however, have been pointed out that Mr. Taylor, of Leicester, was the real discoverer of the fact. Long before the Wild-Barfield process was perfected, it had been found that, for small articles, Taylor's magnetic device for hardening was very valuable. It was only useful for small articles because, in order to keep the necessary rate of cooling through the carbon change point, it was essential that there should be a higher initial temperature, varying with the mass, than that which was given to the magnetic change point; consequently the larger mass would fall away from the magnet before its proper time. The diagram shown in Fig. 1 of the paper was, the speaker said, incorrectly marked. The remark "lines bound points of arrest or recalescence" was also incorrect; they did not so bind.

Colonel Crompton felt that he expressed the views of a considerable body of the engineers best informed on screw standardisation in saying that it was much to be deprecated that inventors and thoughtful people like the author had directed their efforts to the perfection of the screw gauge instead of to screw-forming tools, which were far more important as a means of obtaining interchangeability. Even the extraordinary war conditions, demanding the simultaneous gauging of the great quantity of material failed to obtain interchangeability, unless the limits of error were excessively large. Moreover, it was found that the wear of gauges, even when case hardened, was very considerable, and they were not interchangeable from that cause. It was now understood that distortion was also a matter of ageing. Only those who had been engaged upon the work many years understood the slow changes which took place, and how gauges which were in pitch when manufactured were wiped out of use a year or two later.

At a very early stage of investigation, the late Mr. Clements, and the speaker had found that case hardening did not produce gauge surfaces hard, but the gauges were very good as reference gauges. Then, as now, the speaker's efforts had been directed to the more difficult business of the screwing tools, particularly taps. That portion of the work had not, however, advanced as it ought, time and energy having been deflected to the gauges. In his investigations, the speaker was now doing for taps, apart from some of the modern air-cooled steels, everything that had been done for gauges. There was, however, this difference, that gauges had rarely more than one diameter of length, whereas taps were generally two or three diameters long. Even in such difficult cases he could assure screwing tackle manufacturers that the day had come when tap error could be cut down to something like the figure mentioned in the paper for gauges. He would conclude by observing that the matter had now become the special subject of a panel appointed by the Tools Committee of the Institution, and, with the advantage of having before them a bibliography recording all that had been done, rapid results should follow.

Mr. J. F. Driver was the next speaker. He said that it had been stated in the paper that the author had fallen back on the cutting tool itself for the accuracy demanded, assisted by the use of a very mild steel of 0·14 per cent. carbon for the blanks that cut with a polish. He desired to know what cutting compound was used, and whether the blanks were subjected to any previous heat treatment; if so, whether steps were taken to ascertain that the total carbon content of the steel was the same after treatment as before. At the Loughborough Technical College it was the custom to use steel having 0·2 per cent. carbon. After roughing down, the blanks were embedded in charcoal and heated at a temperature of 850 deg. C. for four hours. They were then allowed to cool down and reheated to 830 deg. C. and quenched in water at 20 deg. After that they were tempered by immersion in a salt bath containing temper melt at a temperature of 370 deg. C. In that condition the blanks had a hardness of 67 scleroscope and were just soft enough for a cutting tool to work upon; an excellent finish was received. The point of interest was this, that in all cases the carbon content of the steel appeared to increase. On the previous day he had had a piece of 0·15 per cent. carbon steel treated in that manner, and careful analyses of drillings from the centre core—not the casing—of the steel showed that the carbon had risen to 0·23 per cent.

He suggested that the pyromelt store-furnace mentioned in the paper was unnecessary. Experience showed that if a gauge were taken from the cyanide bath and put straight into an ordinary muffle furnace sufficient cyanide clung to the surface to prevent any appreciable formation of scale. It would be interesting to know at what temperature the pyromelt bath was maintained, and what was the estimated fall in temperature of the gauge

in passing from the pyromelt bath to the quenching bath. Experience showed that specimens of commercial steel varied considerably, and Mr. Driver enquired whether the seven specimens in the tests were taken from the same bar, and whether the analyses given were verified by experiment. He would also like more details as to annealing, referred to in the paper. Did the author suggest water hardening at 700 deg. C. and oil hardening at 717 deg. C. for all classes of steel, irrespective of their carbon contents? It had been stated that the steel specimens were glass hard, but the speaker, notwithstanding that he had dealt with thousands of samples of steel hardened in cyanide, had never obtained a sample that could be classed as "glass hard." The file test, he would suggest, was unreliable, and he regarded it as unfortunate that the hardness numbers should not have been given. "Glass hard" was usually reckoned as 100 on the scleroscope scale, although it was quite easy to scratch glass with a hardness number of 95. He had scratched with an ordinary file a steel showing a hardness of 103. He had found that the average in the case of water hardening showed a scleroscope number of 85 and with oil hardening—approximately in the manner suggested in the paper—the average number was 67. The numbers 67, 85 and 95 were all easily filed.

Referring to the radial distortion of the gauge, he would ask whether in these distortions the gauge maintained its cylindrical shape. He feared it would assume an oval form; if so, it would become difficult to deal with. The distortions given in Fig. 24 of the paper were far beyond the tolerances put on the gauge. It had been known in the tool room for many years that turned pieces of steel did not distort longitudinally; if it were so it would be very difficult and almost impracticable to make a tap at all. He had plotted a number of curves, from measurements on the pitch-measuring machine, of a number of samples of English and American taps, and in the majority of cases the pitch errors of the taps were well within the limits assigned by the National Physical Laboratory for gauges of the sizes in question. These rather suggested that distortion radially rather than longitudinally might have something to do with the rolling process. When the steel was rolled it was compressed sideways. He had a sample of a piece of steel cut from a 3½-in. diameter bar, and turned across its diameter so that the grain was across a section, and that piece of steel, when hardened in exactly the method the author had suggested, showed a change in length of 34/10,000-in., while its maximum change in diameter was only 2/10,000-in. at any point.

In reply to a question as to ratio between diameter and length, Mr. Driver gave the diameter as about ¾-in. and the length as 3·6 in.; the piece was taken from a 3¾-in. bar.

Mr. Driver stated that he had taken tests of some samples of high carbon steel pieces hardened in a tube furnace. The samples had been made a considerable time ago, and he hardly ventured to state the change in size due to ageing, since the change was so extraordinary that it might be criticised. With the high carbon steel the change in length in the maximum place was 1/10,000-in., whereas the change in what he would call its "maximum elliptical distortion" was 6/10,000-in.; the ratio diameter-length was about 3. He would suggest that other liquids than oil and water might be tried for hardening. In his tool-room days success had been achieved with hardening in a cutting compound—an emulsion of lard, oil, soda, and so on—which constituted something between the two extremes. He had also seen rather good results, with respect to distortion, in screw gauges hardened in urine after treatment in cyanide. He would submit figures of the gauges he had with him. With water-hardening at 700 deg. C. and afterwards heated in a muffle at 750 deg. C. the average hardness number by scleroscope was 74, and the elliptical distortion was comparatively small, the maximum being 8/10,000-in. Also water hardened, but with the bath at 740 deg. C. the hardness number was 88 and the elliptical distortion slightly greater; while water-hardened at 800 deg. C., the hardness number was 89 and the elliptical distortion still greater. His average results with oil-hardening were a hardness number of 67 and an elliptical distortion of 7/10,000-in. With a gauge hardened in an emulsion the hardness number was the same as with oil-hardening, but the elliptical distortion less.

Mr. G. H. Ayres raised a few questions. In the first place dealing with water-hardening, he would ask whether allowance had been made in the temperature for the cooling which occurred in passing from the furnace to the tanks, and had there been any local chilling? In the first part of the paper there was no statement of the actual temperature of the quenching baths, although in the second part the suggestion was made that the temperature of the water was 15 deg. C.; that appeared to the speaker too low, and he thought the temperature should be between 20 deg. C. and 26 deg. C., the temperature given, incidentally, for the oil. The qualities and physical properties of oil and water led the speaker to conclude that the higher temperature should have been for water and the lower for oil. During the war he (Mr. Ayres) had conducted certain experiments for a firm, and from them he would suggest that the distortion bore some definite relation to the quenching temperature, consequent upon the actual shock received. With regard to the curves shown in Figs. 24a and 25a of the paper (from 0 deg. to 180 deg. C.), he assumed these curves to refer to half pitch. If that were so, the gauges would appear to have been dropped horizontally, which would account for the distortion. In a case like that he thought the gauges should be dropped vertically. He would also ask if any definite experiments had been carried out using a layer of oil on the top of the water? Whilst with a perfectly plain cylinder the layer of oil might have no effect in relieving the shock by the water, in the case of a thread there was the possibility of the oil being carried down—due to the V-shape of the thread, If that were practicable, it might be possible to reduce the distortion caused in the water to an amount equivalent to that of the oil, and also secure the reliability shown in Fig. 13 of the paper, where all the curves crossed at one point.

Dr. A. Bramley spoke next. He referred to the cheese-shaped disc adduced in the paper as an example of distortion, concerning which it was stated that the volume remained unchanged; it was also affirmed in the paper that by a law of nature the volume remained unchanged. The change in hardening was, apparently, very small indeed; that had been the speaker's experience, and he had had no difficulty in keeping the pitch, but had had considerable trouble with the diameters, which almost invariably grew. In the example of the cylinder, cut crossways from a 3¾-in. bar, which his colleague, Mr. Driver, had mentioned the change in diameter was 2/10,000-in., showing a decrease, but the change in length was 34/10,000-in., so that, on the whole, there was a definite increase in volume. The examples quoted in the paper nearly all showed increases, a fact which was rather inconsistent with the two statements that the total volume did not change. It had been his experience that in hardening from the temperatures given there was a probability of getting soft spots, and he invariably hardened or quenched from a higher temperature. With regard to quenching in oil or water, he could never obtain the same hardness with oil as with water. He had difficulty in understanding how untapped gauges having the elliptical distortion shown in Fig. 25 of the paper were possible. Finally, with regard to the five curves shown in Figs. 8, 9, 10, 11 and 12, and their superposition in Fig. 13 of the paper, he presumed the author had not depended upon one set of experiments; before stating that at 700 deg. C. there was a constant distortion. He (the speaker) would be disposed to carry out a large number of experiments, as, seeing that, at any other temperature, the curves were all over the place, the result might be due to coincidence rather than law.

Mr. J. E. Baty stated that during the previous week he had carried out one or two experiments bearing in mind the particular dimensions of the test pieces dealt with in the paper, namely, 9/16-in. diameter by 0·7-in. long. He believed the results shown by the super-imposed curves of the paper referred to that size only. The particular piece he had taken was 2 in. in diameter and 1 in. long, with a ¾-in. hole through the centre and was screwed on the outside. It was a piece of Ubas steel not carburised, hardened at 760 deg. C. and quenched in cold water. The idea was to find out if the length measured on the cylinder conformed to the actual pitch measurements taken on the screw, as during the last few years the speaker had found numerous cases in which this has not happened. The pitch error was as near as could be +0·0002 measured along the screw (mean of four places). On hardening, this altered to —0·0015, a total difference of 17/10,000-in. The average length, overall length, from soft to hard of the test piece went down —0·0004, showing that, in that particular instance, you could not take measurements over the plain cylinder to indicate what is going to happen to the pitch of the screw.

A second test piece of similar size, 1⅛ in. length, but with no hole through it and a handle on one end, was taken. In this case there was a difference of 13½/10,000-in. between the end and pitch distortion, and Mr. Baty contended that with any cylinder taken the distortion depended absolutely upon the length of the cylinder compared with the diameter. There were numerous variables to be taken into account with which the late Mr. Lineham had not dealt in detail. As he had just pointed out, one of these was concerned with the relation between the screw portion and its diameter, and another was the pitch compared with diameter. With a very big helix going round, the figure obtained would be very different from that resulting from a very fine thread. Then there was the length of time in the bath. The cyanide showed a great tendency to stiffen or hold up the steel in the hardening; consequently the strength of the cyanide bath was an important factor. If constant quantities were not added and constant temperatures maintained, there would be a constantly fluctuating carburising power in the cyanide bath. Again, as mentioned by the previous speaker, the effect of the temperature of the quenching bath was a further point.

Turning to experiment No. 8 in the paper, Mr. Baty said that the author had found what he (the speaker) had been trying to demonstrate. In this instance the gauge was 1·15 in. in diameter with 1 in. length of screw, and a totally different result was obtained, which suggested, as the author had said, that length was a factor in total extension. Mr. Baty contended that the experiments 8 and 9 disproved the whole of the first part of the paper. Further, he would say that the cyanide bath was quite appropriate for small gauges but with a gauge of very large diameter, with a big body of metal inside, the heat had to get out, and the only place for it to get out was through the small walls that had been cyanided; consequently, with large-sized gauges, a soft surface almost always resulted. One or two speakers had mentioned that if the gauge were withdrawn at the recalescence point, it was necessary to be quick in transferring it to the quenching bath. Steelmakers, however, contended that hardening should be done on a rising temperature, and that a fairly big range should be given after the carbon has gone out of solution again. In his first paper the author had allowed for a distortion of 3/10,000-in. in pitch, and regarded that as correct because it came within the allowance made by the N.P.L. As a matter of fact the tolerance of 6/10,000-in. allowed at the N.P.L. for small gauges included the pitch error, the measure of the effective diameter and also the measure of the angle. Therefore with 3/10,000-in. there was nothing to spare either for diameter errors or errors of angle.

Mr. F. H. Rolt stated that he had visited the Goldsmiths' College while the late Mr. Lineham was engaged on the steel gauge problem; he had also tested a number of the gauges made and had found them really excellent. Most of the author's gauges were small B.A. gauges, and the like, and with that size of gauge the results obtained were first-class. The limits Mr. Lineham worked to on some of the gauges were extremely fine, not the ordinary limits of 6/10,000-in., but check gauge limits, and the percentage of passes was quite large. Towards the close of the war, the Ministry of Munitions placed great reliance on Mr. Lineham for producing very small gauges. Mr. Baty had dealt with the question

of making experiments on the 9/16-in. by 0·7-in. specimens and using the results for gauges of quite a different size. The speaker had himself an idea that the distortion produced in hardening was largely dependent upon the form of the gauges. A long spindle, say, 0·1-in. in diameter by 6 in. in length, would distort quite differently from a 1-in. cube. That was why he contended that it was unsafe to experiment with a sample of steel of a different size from the actual gauge which was finally to be produced. He had been surprised at the remarks on the pitch of taps. Generally speaking commercial taps were made to any pitch, presumably because the methods of hardening were not very precisely carried out.

As Colonel Crompton had said, the question of taps and screwing tackle generally was at the root of the whole screw gauge problem. It was useless to go into the question of accurate screw gauges if the work produced was of a bad character. With regard to quenching, charts were given in the paper to show that the quenching temperature was so and so; that temperature, he presumed was the temperature at the bath. But what was the temperature of the gauge when just going into the quenching tank? Surely there would be a considerable drop in passing from furnace to tank? He believed there were furnaces on the market which permitted immediate transposition from furnace into the quenching bath. The general principle applied to these furnaces was to have a tube surrounded by an electric coil, the heating being done in a reducing atmosphere. Gas passes up from the bottom of the tube and is ignited at the top where it emerges; the tube itself came down very close to the cooling tank, which might contain either oil or water. A pyrometer was inserted in the tube and the gauge was heated to the required temperature. All that was necessary was to take away the supporting bar, or whatever it might be, and the gauge would drop straight into the tank. It must be admitted that it would have to pass through a slightly cooler temperature towards the end of the tube; but there was no taking the gauge out of the furnace through fairly cool air and letting it cool down comparatively slowly and then go into the tank. Although not a metallurgist he had gathered that the question of hardening was dependent upon sudden cooling from a certain temperature. It was useless to let the gauge cool over a range of even a few seconds; the cooling must be practically instantaneous. These furnaces, the speaker said, had also a great advantage in the fact that no oxidation took place. One great trouble in hardening was attributable to the formation on the gauge of a scale, which, even supposing that the gauge was not distorted, it was necessary to remove; the gauge was not serviceable with a scale on it.

Mr. G. T. White observed that he proposed to reply to the several questions raised in writing. The very numerous criticisms were not unexpected but, in defence of the paper he would say that the experiments were carried out at a time of very great stress. It had been difficult to get definite information in connection with the distortion of steel on quenching. The problem had been to turn out gauges during the severest period of the war—early in 1918—and there had been no time to go into fine scientific detail. Mr. Lineham's experiments had been made partly with the object of finding information for himself in order to enable him to make gauges, so that the manufacture of aeroplanes might be expedited. He felt that the members present had probably gained more useful information from the criticisms and questions than from the original paper.

Mr. W. H. Patchell, Member of Council, desired that members should not in any way misunderstand the President's remark on the "stage management" of discussions. The object in view was so to stage the discussion as to ensure its being full and adequate. The Council had no intention of limiting what a man might say for or against a paper. It sometimes happened that papers did not get into the right hands. Frequently people spoke on a paper which they had not, as they admitted, read. That was not fair to the Institution, and the Council were very desirous that every paper should be fully discussed.

The President then stated that he was informed that Mr. Agnew, of America, was present. Mr. Agnew had come to this country in connection with screw threads for light automobile cars, and in expressing a welcome to Mr. Agnew, Captain Sankey invited him to make a few remarks on the paper.

Mr. Agnew said that he was quite unprepared to discuss the paper, but was glad to have had an opportunity of attending the meeting. He would like to say that the experience which the British Engineering Standards Association and associated societies had placed at the disposal of the Americans had proved an inestimable benefit in forming their new organisations and getting them well under way. The co-operation between the two great English-speaking nations was of first importance to them as citizens and engineers, resulting largely, as it did, in real amicable relations.

The President then announced that the paper would be further discussed in Manchester on April 29, and that the last informal meeting of the session would be held on Friday, the 30th inst. The debate on "Planing *v.* Milling" would be opened by Mr. J. E. Baty, Associate Member and Mr. G. H. Hughes, Member. Particulars of the summer meeting had been issued to the members.

The Annual Dinner.

The annual dinner of the Institution was held at the Connaught Rooms, Great Queen Street, W.C., on the 22nd inst., and proved a very successful function. Captain Sankey presided over an attendance of something over 300 members and guests. After the usual loyal toasts had been proposed by the President, Mr. W. H. Patchell proposed "The Houses of Parliament." This toast was replied to by the Rt. Hon. the Lord Chancellor. The toast of "His Majesty's Forces" was proposed by the President and that of "Kindred Societies" by Sir John Dewrance. The latter was replied to by Sir J. J. Thomson, President of the Royal Society, who stated that he was originally trained for the engineering profession. Sir John Aspinall proposed the "Visitors," and Sir John P. Griffith the "Institution." Speaking as the President of the Institution of Civil Engineers, Sir John P. Griffith said that there had been difficulties in connection with his institution's proposal for the registration of engineers, but they had been dealt with by good temper on all sides. Captain Sankey in his reply referred to the same matter and said that it was proposed to have a conference of leading institutions which it was hoped would lead to a conjoint board of examination.

A NEW LIQUID FUEL.

In the present state of the fuel situation in this country any development of new sources of supply, or any method of utilising existing sources more effectively, is of interest and importance. An example of the second type is furnished by a new liquid fuel which has received the name of Colloil. The development of the method on which this material is produced would appear to carry important possibilities. Colloil is briefly a mixture of a fuel oil with coal or coke dust so treated that it has been brought to a partially colloidal state. The mixture may be burned in the same way as liquid fuel. If this mixture is made up with a bituminous coal dust, then clearly it becomes a direct competitor with the various methods of powdered fuel firing. From this point of view we have no information about the case which can be made for it. It is not, however, as a direct competitor in this way with powdered coal firing that the material is brought forward. Its essential claim, from a commercial point of view, is that fuel dusts which are difficult or impossible to use in any other way may be pressed into service and may be completely and satisfactorily burned in an ordinary furnace. It is particularly in connection with the utilisation of anthracite dust that the material and method would appear to be of importance.

Colloil has been developed and patented by Mr. G. C. Calvert, of the Metropolitan Laboratories, "Elmhurst," Twickenham Park, Middlesex, and we recently had an opportunity of seeing a furnace in operation at that place burning the fuel. The Colloil which was used was made up from anthracite dust with a fuel oil and the combustion appeared to be perfect. There was little smoke at any time and none when the furnace had been running a short time and the regulation was carried out with ease. As anthracite dust is difficult to use in any ordinary way, and is to some extent a waste product, its effective burning in this way should be of commercial importance. We understand that it may be purchased even now at a few shillings a ton. The percentages of dust and oil in the mixed fuel are about 1 to 1, and it can be treated and incorporated with the oil at about 15*s.* a ton. Assuming it has roughly half the calorific value of the oil, weight for weight, the mixture clearly shows a great saving over unmixed fuel oil at, say, 12*l.* a ton.

The preparation of the coaldust is obviously an important feature of the new fuel. It would be possible to bring it into almost true colloidal solution with the oil, but the time and cost of this operation make it a prohibitive one from a commercial point of view. What is actually done is to bring the solid fuel into a levigated condition so that it mixes easily with the oil and remains suspended for a considerable time. In use the fuel has to be agitated either mechanically or by bubbling air through it. In the preparation of the solid fuel it is first ground to a fine powder and then incorporated in a mill with a levigating agent tending to alter its surface tension relative to the oil. Suitable levigating agents are soap, fatty acids, tar or silicate of soda. The dust is treated in a mill with a little of the levigating agent, dissolved in water or other agent, for about an hour. About one part of the agent to 1,000 parts of dust is used. At the end of the hour the liquid fuel carrier is added, and milling is continued for several hours longer. It is then ready for use. It is not necessary that the whole of the fuel oil which is to be incorporated in the final mixture should be handled in the factory in which the levigation is carried out. The prepared dust with a small proportion of oil may be put into casks and shipped, and the final proportion of fuel oil added on the site where the fuel is burned.

As Colloil contains solid matter in suspension it is not suitable for passing through needle valves and special arrangements have to be made for regulation at the burner. These arrangements are, however, of a very simple nature. In the plant which we saw in operation the mixture was delivered by a pump through a small pipe and fell on to the top edge of a diaphragm contained in a cup. An orifice led from the bottom of the cup back to the oil tank, while a second orifice led to the burner. The two orifices were on different sides of the diaphragm and the position of the latter could be adjusted horizontally by means of a lead screw and milled nut. By moving the diaphragm, more or less of the fuel passed to one side or other of it, so that the amount of fuel reaching the burner could be regulated. The fuel was not supplied to the burner under pressure, but ran down a pipe from the regulating cup. At the burner it flowed over a weir and was caught by a blast of air and sprayed into the furnace. The burner used was a standard liquid fuel burner not modified in any way except that the valve control was removed. The fuel in the tank was agitated by a rotary splasher driven by the same motor which operated the pump and the air compressor. The air was used at about 20 lb. per square inch. It is clear that a simple way to regulate the burner would be to control the fuel supply from a pump, the speed of which could be varied.

The German Transatlantic Electric Company.—We read in *Revista Minera*, Madrid, that the Deutsche Ueberseeische Elektrizitäts Gesellschaft, known in Buenos Ayres as Compañia Alemana Trasatlantica de Electricidad is being converted into a Spanish company, with offices in Madrid. The company, says the Madrid journal, was the most important German concern of the kind operating abroad before the war. Closely linked to the Deutsche Bank, it was one of the instruments of national expansion. It has interests in the Buenos Ayres and Quilmes Tramway Company, the Argentina Electric Company, the Chilian Electric Tramway and Light Company, the Valparaiso Electric Tramway Company, and others. The Madrid journal adds that the *Frankfurter Zeitung* and all other German periodicals deplore the loss of this powerful organisation, and that one-third of the capital of the original company is in the hands of non-German citizens, most of whom are of Swiss nationality.

British Engineering Standards Association.—We have received from this association a copy of their British Standard Pamphlet C.L. 8,564—1920, of rubber tyres for British standard rims, which has just been published. It states that the urgent need for reducing the great number of sizes of rubber tyres in use on automobiles having been recognised by the British Rubber Tyre Manufacturers' Association, a scheme for that purpose was suggested by them and submitted to the British Engineering Standards Association for consideration. The scheme was considered, and certain modifications were made to the proposals; these were embodied in the pamphlet now published and have been accepted by the British Rubber Tyre Manufacturers' Association. In consultation with the American Society of Automotive Engineers, the American standard tyre sizes, both pneumatic and solid, have been included, a further step thus being taken in the direction of Anglo-American co-operation. Copies of the pamphlet can be obtained from the British Engineering Standards Association, 28, Victoria-street, S.W. 1, at the price of 1*s.* net; and 1*s.* 2*d.* post free.

HIGH-SPEED CRAFT DURING THE WAR.*

By Mr. W. W. MARRINER.

To be able to move quickly, apart from its utility, has always a charm, and the advantages of high speed in warfare are so evident that it is hardly necessary to emphasise them. A higher speed than that of the enemy gives the advantage of position, and also the power of accepting battle or not, so that full advantage may be taken of any superiority in armament, or if the enemy has the more powerful weapons it is possible to keep out of his way.

Speed, however, cannot be obtained without paying the price, and whether it is the rate at which one lives, or the speed of an express train or the speed of a vessel, in every case something has to be sacrificed in order to obtain what is desired. The amount of energy at our disposal is limited, and if we want to move quickly we must reduce the resistance to a minimum and utilise the maximum energy.

I have had the honour of being associated with Messrs. Yarrow during the whole of my career, and consequently my description in this paper of high-speed vessels is limited to what has been accomplished by this firm. I am quite sure that Sir Alfred Yarrow and Mr. Yarrow would be the very last to refuse a tribute to what has been done by other firms and individuals in the development of high-speed vessels.

One of the most renowned firms in this country is that of Messrs. Thornycroft, and the development of high-speed vessels owes much to the bold advances which have been successfully made by that firm from time to time, both in design and in taking advantage of the best available materials. Not only did they build many high-speed destroyers during the war, but they evolved a most successful high-speed coastal motor boat. The feats accomplished by these coastal motor boats are some of the most remarkable of the war. Any results which may have been obtained by them are, in the first instance, due to the skill and endurance of the officers and men of the Navy, but Messrs. Thornycroft deserve the highest praise for designing and building such wonderful craft.

Mention might also be made of the splendid work done in the early days by M. Normand, the great French designer, our friend and rival. As an instance of business chivalry it might be of interest to you to relate an incident which happened many years ago when rivals were struggling to be the first to obtain 30 knots, and in the end it came to a neck and neck race between the firms of Normand and Yarrow. The Yarrow boat was finished first, and on trial obtained the coveted speed of 30 knots. Concerning this performance the first congratulatory telegram received by Messrs. Yarrow was from M. Normand, and it is a telegram which we prize more than any other received at the time.

The title of the paper is "High-Speed Vessels during the War," and this enables me to draw attention to the splendid work done by passenger vessels, by high-speed steam yachts, by racing vessels of all kinds, and by hydroplanes, and it will be agreed that the lessons learned in some of these sporting vessels have advanced our knowledge in a most useful way.

In acknowledging the magnificent work which has been achieved by other builders of destroyers, the worker in science, and the pioneers in the various fields of industry, such as steelmakers, makers of turbines, and makers of auxiliary machinery, should not be forgotten, all of whom have contributed to making high-speeds possible.

In the design of a high-speed vessel it is necessary to make a careful study of the conditions under which she has to operate. A vessel for a shallow river is quite a different proposition from a vessel operating at sea, and again a high-speed vessel which has to operate on a short radius of action is very different from one which has to operate at a great distance from its base. The governing principle, however, remains the same, namely, resistance must be reduced to a minimum and power must be obtained most efficiently.

Consider, first of all, the question of weight, which is a large factor in resistance. It may be divided into weight of hull, weight of machinery, weight of crew and armament, and weight of fuel. The weight of armament is fixed by the military authorities (especially those of the enemy) as it is useless to get into a position to strike a blow, unless on arrival the blow can be made effective.

The total weight is largely influenced by the all-important consideration of cost. Having determined the total displacement it is then possible to allocate what weight can be allowed for the hull and for the machinery respectively. If the vessel has only to make short raids and return immediately to her base, then it is obvious that the scantlings of the hull and the accommodation for the crew can be reduced, because the vessel can choose the weather in which she puts to sea, and the crew can put up with a fair amount of hardship for a short period.

In the late war the Germans made full use of this condition, and their destroyers used to put to sea with a minimum of fuel and outfit on board, with the consequence that in many cases they were able to outdistance British vessels which had naturally to be prepared for keeping the sea for an indefinite period in all kinds of weather.

Generally speaking, in the modern destroyer the distribution of weights is approximately as follows:—

	Per Cent.
Weight of hull	35
Weight of machinery	35
Weight of armament and stores ...	7
Weight of fuel	23

Having settled the weight which can be allowed for the hull, one can decide the dimensions of the vessel. For speed the important dimension is the length, for stability the important dimension is beam, and for strength the important dimension is depth. The length is, therefore, influenced by its relation to the beam and depth of the vessel, and it is here where the skill of the naval architect is shown by obtaining the very best compromise as regards the dimensions to be adopted, always keeping in view the special service for which the boat is to be employed. A vessel which has to be constantly employed with a fleet, and whose speed is determined by the senior officer of a larger ship, should be made stronger than the vessel, which will only have to act independently or with vessels of its own class, when the senior officer of the flotilla is himself experiencing the shocks caused by waves. Even in a comparatively calm sea there is a certain speed for every vessel where the synchronism of the waves with pitching might become serious.

Much can be done by arranging weights relatively to the buoyancy at any part, so as to reduce the bending moments, and present-day lightness in hull construction has been attained without any sacrifice of strength or decreasing the factor of safety, by a scientific study of the stresses involved and the best disposition of the material.

Having decided upon the dimensions of the vessel, the next important consideration is the form of the under-water hull, and in this connection tank experiments are valuable; in fact, essential. One can hardly believe that twenty years ago it was necessary to go to Germany in order to have tank experiments carried out, although there were private tanks in this country which, however, were not available for public use. The form of the vessel is important not only from the point of view of reducing the resistance of the hull to a minimum, but also to ensure that the propeller works with the highest possible efficiency. From tank experiments it is possible to form a close estimate of the power required to drive the vessel, and for a given speed it is just as important not to over-estimate the power as it is not to under-estimate it, because the weight of the machinery may be taken to be proportional to the power, and excessive weight of machinery means a load to be carried increasing also the weight of the hull, and thus doubly reducing the speed.

Possibly sufficient attention has not been paid to the underwater form from the point of view of obtaining the highest propeller efficiency, especially in vessels where the power is proportionately very large. It is well known that at high speeds the propeller is one of the most inefficient parts of the propelling installation. Models have been equipped with propellers driven by motors installed on the model and a measure taken of the power required by the motors. Naval architects in this country at one time would not place much reliance on results obtained in this way, but owing to the researches carried out by Mr. R. E. Froude at Haslar, and Mr. Baker at the William Froude National Tank, Teddington, means have been perfected by which accurate investigations can be made, and experience has proved that the methods adopted by them are sufficiently accurate to form a reliable guide. As long ago as 1903 Sir Alfred Yarrow advocated a flat-bottom stern for a destroyer in order to increase the propeller efficiency, and H.M.S. "Garry" may be looked upon as an early example of this type of stern for destroyers. The resistance of the hull is hardly affected as compared with the ordinary round-bottom stern, but the propeller efficiency is increased to a remarkable extent, a knot more speed being obtained for the same expenditure of power.

Having fixed on the weight of the hull and machinery, the designer is then in a position to say how much weight can be allowed for the armament and fuel on a vessel of certain displacement. The importance of weight on a modern destroyer may be illustrated by stating the fact that for every pound weight thrown overboard the vessel will be ¼ in. further ahead each hour, or for every ton weight saved half a length of the ship will be gained in an hour's race.

The relationship which exists between the various parts is one of the most important factors in the success of a destroyer, not only from the point of view of speed, but also from the point of view of seaworthiness. Any

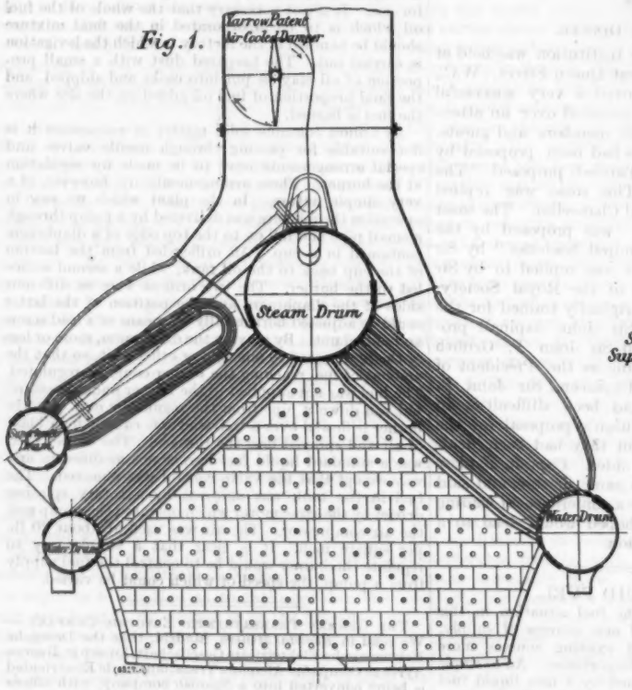


Fig. 1.

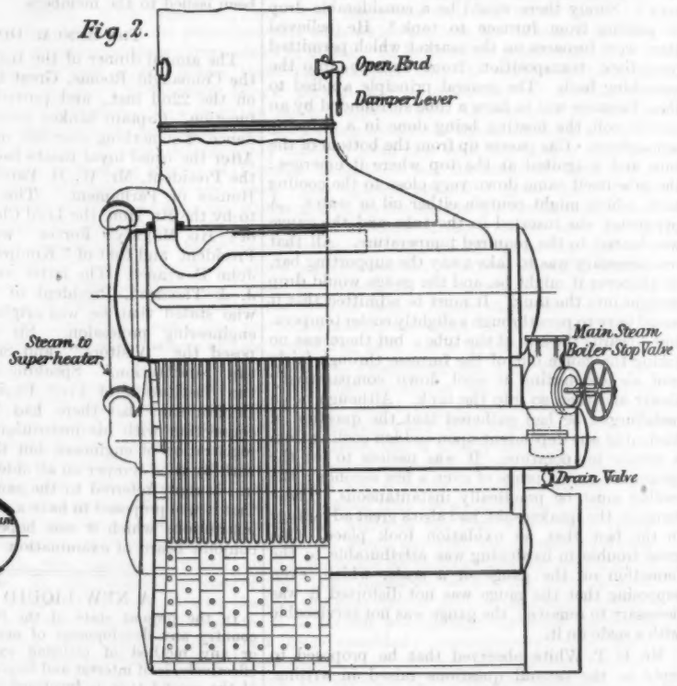


Fig. 2.

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, April 20,

Government Department is in an unfavourable position in this respect as compared with a private firm, because in the latter there is one head who is in a position to settle what he considers to be the best compromise. Sometimes the hull has to be cut down, and sometimes the machinery, and sometimes it is necessary to say that the armament is not suitable for that particular size of vessel. In firms who make their own designs it has been noticed that every now and again a design is arrived at which gives results far ahead of what has been before obtained. For instance, in 1894, Sir Alfred Yarrow constructed the "Sokol" for the Russian Government, which was a vessel 190 ft. long by 18 ft. 6 in. beam, with twin-screw engines of a total indicated horse-power of about 4,000 and Yarrow water-tube boilers. Her armament comprised one 75 mm. gun, three 47-mm. guns, and two deck torpedo tubes. She was the first vessel to attain a speed on trial of 30 knots, and this result was obtained principally by the adoption of water-tube boilers, and high-tensile steel in the construction of the hull. This special steel had a tensile strength of from 37 tons to 44 tons per square inch, and an extension of not less than 15 per cent. in 8 in. for plates $\frac{1}{4}$ in. thick. Its application permitted a reduction in thickness of 12 per cent. below that of the mild steel previously used, with such a saving in weight of hull that an extra knot was added to the speed. All the stanchions were made hollow, pressed steel was used wherever possible instead of cast metal, and for cabin fittings aluminium was adopted, all in order to save weight. She was built at the same time as other destroyers which had a difficulty in obtaining 26 knots.

The "Sokol" was gradually improved upon in future designs. Keeping as near as possible to the same relationship of weights and form, and taking advantage of every modern improvement, what was considered one of the very best vessels they ever built, namely, the Mode, was constructed in 1902 for the Swedish Government. She was 220 ft. 3 in. long by 20 ft. 6 in. beam, and had four Yarrow boilers, and twin-screw reciprocating engines of a total indicated horse-power of 6,400. The speed realised on the official trial was nearly 32·5 knots. For the size and power this was a remarkable result, especially as it was obtained when burning coal under the boilers.

The adoption of oil fuel was perhaps the next great step forward in the evolution of destroyers, and an enormous amount of credit is due to the Admiralty Experimental Station at Portsmouth, which brought oil-fuel burning apparatus to the perfection which is now known. One cannot help feeling that there must be some engineer officers whose names ought to be made public so that due honour might be paid them for their work in connection with one of the greatest improvements for war vessels, especially as it placed this country far ahead of the rest of the world for many years.

In 1910 the Admiralty, at Admiral Jellicoe's initiative, gave Messrs. Yarrow almost a free hand to do the best they could with a certain sum of money. The result was an outstanding design from which the Firedrake, Lurcher, and Oak, were built. Their dimensions were 255 ft. long by 25 ft. 7 in. beam, and each was fitted with Parsons' impulse reaction turbines and three oil-burning Yarrow boilers. One of these vessels on the official trial of 8 hours duration obtained a speed of 35·354 knots.

The next important advance was in the direction of superheating. It had been long known that superheating offered great advantages both as regards economy and reliability, but in spite of many attempts it was not looked upon with great confidence for marine purposes. It was, however, so attractive that a special marine superheater was designed and fitted on one side only of the Yarrow boiler, by which arrangement the superheater is placed under control, and that without seriously interfering with the total output of the boiler (see Figs. 1 and 2). If too much superheat is being obtained it is possible to send a larger proportion of the gases up the side of the boiler where there is no superheater, and although there might be a trifling loss in efficiency, yet the total output of the boiler is not substantially reduced. If the superheat is not sufficient, then more of the furnace gases can be sent up the side of the boiler on which the superheater is placed. This control of the amount of superheat was found very valuable, especially in the experimental stage.

It may here be mentioned that with a properly-designed Yarrow boiler having the superheater on one side that higher efficiencies of the boiler plant have been obtained than with a boiler without a superheater, that is to say, more heat units have been transferred from the oil fuel to the steam produced. This result is rather remarkable, and points to the high efficiency of heat transference in a well-designed superheater.

Owing to the adoption of superheating, in 1913 and 1914 we were again able to produce a destroyer which had a very high overall efficiency. Although superheating had been tried in previous vessels yet the most successful results were obtained in vessels of the Miranda Class in 1913 and in 1914, and it was on this type which Messrs. Yarrow concentrated during the war period.

These vessels showed plainly the advantage of superheating for war vessels apart from efficiency, namely, the ability to rapidly increase speed. It is necessary to exercise great care when increasing speed rapidly on account of the water which flows with the steam, and on account of the condensation which takes place in the engines and turbines while they are being heated up to the full-speed temperature. This presence of water is completely avoided if the steam is superheated, because the superheater itself is a large reservoir of heat, so that although the rate of evaporation in the boilers is very rapidly increased, yet the steam arrives at the engines perfectly dry, and in most cases superheated, thus having some surplus heat available in order to raise the temperature of the turbine itself. A further advantage of superheating is that the engine-room is much cooler and consequently more comfortable. It is always noticed during a race in which destroyers take part that those fitted with superheaters get away much quicker than those using saturated steam, and a start of a mile or two is a very valuable asset in a fight. Vessels of the "Miranda" type (see Figs. 3 to 13, Plate XXXII) are about 270 ft. overall, beam 25 ft. 7 in., and depth amidships 16 ft. 3 in. They have three Yarrow superheating boilers, and are fitted with two turbines of the Brown-Curtis type driving directly the propeller shafts without the intervention of gearing. Brown-Curtis turbines were applied to these vessels on account of the large clearances in this type of turbine which made the use of superheated steam quite safe. Sir Thomas Bell, Engineer-Commander Wood, and Mr. Pigott deserve great credit for the investigations they carried out at Clydebank to make these Brown-Curtis turbines a success not only on destroyers but also on much larger vessels.

In the first vessels of this class a speed of 35 knots and a radius of action of 2,500 knots at 15 knots was guaranteed. In the last vessel of the class, the Tyrian, a speed of 39·7 knots and a radius of action of 3,267 knots at 15 knots was achieved. This speed was obtained on the Skelmorlie measured mile in deep water, which is recognised as being the standard mile for high-speed vessels, it being well known that in water of a less depth the hull resistance is reduced at high speed and fictitious results may be obtained.

We ought to be very grateful to Messrs. Denny of Dumbarton for providing us with the Skelmorlie mile, which is acknowledged to be the best mile in the world.

High-speed vessels owe a great debt to them for providing the means of obtaining the accurate data on which future progress is based.

When speaking of the measured mile it may not be out of place to propose that a new deep-water measured mile be set up off the north end of Arran, close to the Cock of Arran, and running approximately north-east and south-west. On this course there is plenty of room at the end for the largest vessel to turn round safely and to attain the full speed before entering on the measured distance, while the depth of the water is not less than 40 fathoms.

It is sometimes overlooked how much power is absorbed in accelerating a vessel after the speed has been reduced by a turn at the end of the measured mile.

From careful surveys that have been made off the Cock of Arran, it may be possible to obtain a base 2 sea miles long, which would lead to more accurate results at high speeds. The measured distance would be in a sheltered position, clear of the traffic, and it would have the great advantage of the course being parallel to the shore. Anyone who has run high-speed vessels will know the difficulty which the pilot has in quickly getting his bearings, for when travelling at 40 knots there is not much spare time to get the correct direction after the turn at the end of the mile, and the direction of the line of the shore is a better guide than swinging compasses. The only reason for proposing a new mile is because the large vessels and high speeds of to-day make it undesirable to run so near the growing excursion traffic and so close to the foreshore of a residential neighbourhood.

One of the most satisfactory features of war experience is that vessels of the "Miranda" class suffered little or no damage due to sea conditions. They proved quite strong enough for the various kinds of work that they were called upon to perform, sometimes under the most trying circumstances.

The Mounsey, under command of Lieutenant Craven, was the means of saving 696 people from H.M.S. Otranto. The sea was very rough at the time, and the Mounsey could not lie alongside the Otranto. She had to steam slowly past while the crew of the latter jumped to her deck, which manœuvre she repeated several times. The bumping to which the destroyer was exposed during this operation can be easily imagined, but the structure was uninjured.

Another case of interest as showing the strength of these vessels was when the Musketeer went to rescue the crew of the King Edward. The King Edward had overhanging sponsons, and while taking the crew off in a heavy sea, the destroyer got underneath the sponsons which were descending at every roll of the ship on the deck of the destroyer and severely punishing her. Incidentally it may be mentioned that there were some high-explosive shells in the ready racks on the deck of the destroyer which caused the captain a good deal of anxiety each time the sponson struck the deck, but fortunately none of them went off. In this case several plates were actually torn away, but the main structure was uninjured, and she was quickly repaired and again ready for active service.

It is not generally realised how severe are the tests to which high-speed vessels are subjected by the gun armament. When one considers the recoil of a 4·7-in. gun on such a light structure, or the recoil of a 4-in. gun repeated 20 times a minute, it is remarkable that no ill-effects are experienced. One of the tests on a gun trial is that a man should be able to keep his eye on the sighting telescope while the gun is being fired. If there is the slightest yield in the mounting, apart from the recoil chamber, it will be seen that the telescope is likely to strike the man a nasty blow. The structures are so designed that the gunlayer has no difficulty in keeping his eye fixed on the target even while the gun is being fired.

The success of these light structures is in a measure due to the uniformity of elasticity longitudinally, which is a great source of safety. Some vessels have no doubt come to grief through sudden changes in strength, and it appears that uniformity of elasticity is one of the most important points in this class of light construction.

I think you will agree with me that special credit is due to the designing staff both of ship and engine departments, which can successfully produce a high-speed destroyer, and any firm who have constructed these vessels will know the accurate workmanship which is required and obtained by special overseers appointed by the Admiralty for this type of vessel.

The direction in which further advances in speed may be looked for are as follows: (*a*) Improvements in the shape of the hull, so as to reduce the hull resistance; (*b*) improvements in the shape of the hull in wake of the propeller, so as to increase the propeller efficiency; (*c*) perfect balancing of the propeller, and the removal of the propeller as far as possible from any disturbance which may be caused by the propeller brackets; (*d*) reduction in the weight of machinery by the adoption of high-speed turbines; (*e*) reduction in the weight of machinery by increasing the output of steam from the boilers; (*f*) by the careful elimination of any items which are not necessary for the ordinary upkeep of the ship. To provide for extraordinary occurrences is handicapping the ship by carrying weight which will probably never be used; (*g*) reduction of the skin friction by eliminating all outside transverse laps, especially at the forward end of the vessel, as first pointed out by Mr. Baker.

During the war Messrs. Yarrow were also called upon to design and construct some high-speed gunboats for river purposes, known originally as the China gunboats. In such vessels the problem of speed is entirely different from that of a destroyer.

It is well known that they were ordered by Lord Fisher for use in Mesopotamia, and he gave Messrs. Yarrow an entirely free hand with respect to their design; the only stipulation being that they were to be ready for service in the shortest possible time, and that they were to be a success. Sixteen small vessels were designed and built at Scotstoun, and 12 larger vessels (see Figs. 14 to 19, Plate XXXII) were designed at Scotstoun and built by Messrs. The Ailsa Shipbuilding Company, Messrs. Barclay, Curle and Co., Messrs. Lobnitz, Messrs. The Sunderland Shipbuilding Company, and Messrs. Wood, Skinner and Co. The problem was to carry a certain armament at the highest possible speed on a shallow draught, and at the same time to provide good accommodation for the crew. In the case of the smaller vessels the draught was not to exceed 2 ft. 6 in., and in the case of the larger vessels the draught was not to exceed 4 ft. 6 in. To achieve this result the vessels had to be constructed with a flat bottom, and in order to provide for propellers large enough to utilise sufficiently the power required for the speed, the vessels were fitted with tunnels, so that when at rest the propeller was only half-immersed, and when running the tunnel filled itself automatically, the propeller then working totally immersed. The after end of the tunnel when starting has necessarily to be below the surface of the water to allow for the expulsion of air and to provide an air lock, but when the tunnel is full and the water is flowing through it at a high velocity, the resistance of the vessel can be greatly reduced if the after end of the tunnel be raised up so as to be almost horizontal. This is accomplished by means of the Yarrow hinged flap. The efficiency of this flap can be best expressed by stating that for the same power 10 per cent. more speed can be obtained.

The particulars of these vessels are as follow:—

	Small.	Large.
Length	120 ft.	230 ft.
Beam	20 ft.	36 ft.
Speed	10 miles.	18 miles.

It is submitted that, to obtain 18 m.p.h. on a draught of 4 ft. 6 in. when carrying two 6-in. guns is as good a performance as 39·7 knots in a destroyer.

When mentioning high-speed vessels there ought to be included such outstanding examples of naval architecture as the Repulse and Hood, built by Messrs. John Brown and Co., and the Renown, built by Messrs. Fairfield Shipbuilding Company, which have obtained speeds never thought practicable with such gigantic ships. One cannot help feeling proud of the part which the Clyde has played in obtaining these various record results, and as long as there is the same cordial co-operation between employers, the scientific designing staff and the workmen, there need be no anxiety about records in the future.

MOTOR CARS IN SAO PAULO.—According to an official Brazilian announcement, referred to in *The Board of Trade Journal*, 2,799 motor cars were registered with the police of Sao Paulo up to January 27 last, of which about 140 were motors used for commercial purposes, and the remainder for passengers. This official communication further states that an early increase is anticipated, as the Ford interests alone are importing 500 cars per month into Brazil. By an anomaly of the import dues it is more advantageous to import cars *via* Santos than *via* Rio de Janeiro. The Ford cars are consequently assembled at Santos and shipped to Rio by train, the selling price there being correspondingly higher to cover the extra freight. By far the greater number of cars running in Sao Paulo, at least of the newer ones, are of American make, and H.M. Consul in the city is of the opinion that it will be many years to come before the British-made cars can gain the foothold held at present by American-built cars. The following are the prices of some of the principal American cars being sold on the Sao Paulo market, and, for convenience, exchange has been reckoned at 1*s.* per milreis as, although at the present time the value of the milreis is very much higher, this does not make any difference to the Brazilian customer who pays for his car in currency:—

Ford (standard model) ...	3,600 milreis (180*l.*).
Chevrolet	5,000 milreis (250*l.*).
Dort	6,000 milreis (300*l.*).
Buick (about)	8,000 milreis (400*l.*).

THE PHYSICAL SOCIETY OF LONDON.

AT the meeting of the Physical Society of London, held on March 26, at the Imperial College of Science, Professor W. H. Bragg, F.R.S., President, in the chair, a discussion took place on "*Einstein's Theory of Relativity.*" The discussion was opened by an explanatory lecture on the subject by Professor A. S. Eddington, after which the following contributions were made :—

Mr. Bolton : Professor Eddington mentioned that to an aviator flying at a high speed people on the ground would appear contracted in the direction of motion and *vice versa*, and appeared to deduce from this that certain dimensions of the interferometer in the Michelson-Morley experiment would be contracted. He did not see the connection, as there was no relative motion between the observer and the instrument.

Professor Eddington pointed out that the experiment gave a null result because of this fact ; but the mathematician had deduced the contraction by imagining himself at rest relative to the ether, and therefore having a velocity relative to the instrument.

Sir George Lane Fox-Pitt asked if the observer was always regarded merely as a seeing person rather than a thinking person. Professor Eddington said that by "observer" he meant a person armed with his perceptions and with scientific apparatus where necessary to aid him in making measurements.

Dr. H. Levy said it was difficult to see why of all the possible tracts which a particle might follow it should always elect to follow a geodesic.

Professor Eddington said one reason for identifying the natural tracts of particles with geodesics was that a particle must take a unique tract definable without reference to an observer. The only tract which can be defined uniquely in this way is a geodesic. Mr. T. Smith asked if light in a gravitational field became to any extent polarised. Professor Eddington did not think there was any evidence of this.

Professor A. O. Rankine said, *apropos* of Mr. Smith's question, that a few months ago in collaboration with Dr. Silberstein he had carried out some experiments on this point, the results of which were in the course of publication. Silberstein had shown that according to Einstein's theory a gravitational field should produce an effect on the velocity of light polarised in a plane parallel to the field. The same theory showed, however, that light plane-polarised at right angles to the field would be affected to the same extent, and it was desired to test how far this equivalence was in accordance with fact. A beam of light, plane polarised at 45 deg. to the vertical, was projected in a horizontal direction and examined for ellipticity some distance away. It is evident that if the vertical and horizontal components travelled at different rates, a phase difference would be introduced which would result in elliptical polarisation. No trace of ellipticity was detected, the deduction from Einstein's theory being confirmed. Perhaps the most interesting fact emerging from the measurements was the extraordinary degree of precision with which the two velocities were found to be equal. The difference of optical path of the two components was certainly less than one three-hundredth of a millimetre in the distance travelled in a second, viz., 300,000 km., assuming a gravitational field equal to that of the earth to hold over the whole distance.

Dr. Vincent asked if the theory of relativity applied to the kinetic theory of gases would not oblige us to alter our ideas on high temperatures. The conclusion was probably fallacious, but it appeared at first sight as if the electron could not move with a velocity greater than that of light, and that consequently there would be an upper as well as a lower limit to the absolute temperature scale.

Professor Eddington replied that with our usual definition of temperature as proportional to the energy of the atoms there was no upper limit ; but if the scale were chosen to depend not on the energy but on the square of the velocity, it would reach a finite limit.

Sir Joseph Larmor, in a communication read by the secretary, said the charm of the Einstein train of ideas seems to be traceable to several causes. In the first place it has revived the interest in the Riemann differential geometry, itself a transcendental development of the ideas of the Gaussian theory of surfaces, and the admiration of Gauss for the train of thought of his disciple is on record. Then, again, as it loosens all foundations, its ideas are capable of development in unexpected directions. How far it is from being a determinate theory of the universe will appear to anyone who dips into the writings of its developers. Indeed, if it became fixed and rigid and ceased to reveal unexpected vistas, much of the fascination would be gone. For example, the crowning consideration for the most general relativity, on which special stress is laid by Lorentz, and by Eddington, is the assertion of Einstein that it is only the intersections of the world-lines of particles that can constitute events, and so long as these points retain the same order along their lines, we may give body to their collocation by filling up with any kind of intermediate special scaffolding that we please. There is nothing to restrict it at all. Yet for all that we proceed straightway to assume a space with its 10 gravitational potential functions, and work out its mathematics in the necessary elaboration ; while we learn that ultimately there can really be nothing to limit our choice of such a framework. I observe that Langevin, being a Frenchman, does not shrink from blunt formulation of the full logical consequence. It is, therefore, possible, says he (Société française de Physique, February 6, 1920), to make enunciation of the principle of generalised relativity, in the assertion that the laws of physics have the same form for all systems of reference, in motion (or deformation) anyhow, in virtue of the introduction in each case of its own special field of gravitation suitably distributed. The ensuing problem is then to explain how it is that astronomers, since Newton's time, have persisted in one special and very precise illusion about the distribution of gravitation, whereas really an unlimited choice was open. One answer seems to involve swinging over to the opposite point of view, to the youthful dogmatism of Clifford, that if space could be fully known the whole material universe would be found to be involved implicitly within it. The general dialectic can thus develop many-sided and indefinite ; the necessary co-ordinating consideration appears to be present in a somewhat latent postulate of one space-time continuum, which this unlimited multiplicity constitutes merely different modes of describing. If we would thus reach at bottom an underlying scheme of space and time after the manner of Newton, why should the natural historical order of development in terms of an ether be ruled out *a priori* ?

The guiding philosopher for this type of theory is claimed by Einstein to be Hume, filtered through Mach ; and it certainly affords a wider field for the play of his scepticism than his own illustrations.

The primary consideration in all sceptical analysis is to know where to stop, and, as with Kant in Hume's time, to replace further destructive criticism by constructive hypothesis. For the unresolvable essence of relativity appears to be that we cannot get on without assuming some foundation to which phenomena are referred, and with respect to which they are ordered to the degree that is necessary for our reasonings.

It has not escaped the notice of the creators of the analytical theory that the whole of it is expressible as a corollary, of novel type it is true, to the fundamental physical principle of least action, which adopts that principle to take in the phenomena of gravitation so as to place them in analytical relation to the other physical principles of Nature. Of the fundamental character of that principle Helmholtz, following upon Hamilton and Kelvin and Maxwell, was not the least of the exponents. The original criteria of stress-energy-momentum tensors then shrink to their proper subordinate position. There is then nothing revolutionary about this brilliant theory, unless it be the fiction that time is merely an additional dimension of space, which is inconsistent with the very language in which it has to express itself, and at variance with the different conditions for physical determination in space and in time. That it is convenient to use mixed co-ordinates of time and space is another matter whose bearings were beautifully elucidated by the application long ago of the expressive phrase "local time" by Lorentz ; it is local time varying irregularly from place to place that allows gravitation to come within the least action scheme.

Mr. A. W. Ravenshear said that in the Michelson-Morley experiment the contraction of the apparatus could not be measured by measuring rods or anything of that kind. It therefore required reference to some other system of measurement. What was this ?

Professor Eddington repeated that no contraction could be directly measured by this experiment. We are led to expect it on the assumption that the apparatus is moving relative to the ether. At any moment we do not know whether we are moving relative to the ether or not ; but at some parts of the year we must be, so that if the results of the experiment are always negative we have to deduce the contraction.

A speaker asked how, if curvatures in space only exists round matter, accommodation was found in the theory for the existence of free energy. Professor Eddington remarked that energy also had curvature.

Mr. C. O. Bartrum pointed out that the Michelson-Morley experiment compared the velocity of light athwart the ether stream with the mean of the velocities up and down the stream. Had any experiment been made comparing the velocity up the stream with that down the stream, and did Professor Eddington consider such an experiment was possible ? He asked the question because he had seen it stated that the work of M. Q. Majorana had shown these velocities to be equal.

Professor Eddington said he had heard that statement, but was not in agreement with it. Majorana's work was to show that there was no change in the velocity relative to the observer due to motion of the source or of a reflecting mirror. He did not think an experiment could be devised to test the point referred to as it was necessary to determine the times of arrival and departure at the two ends of the path. This could only be done by clocks, and if you use only one, you must correct for the velocity of light, which is the thing you are trying to measure.

Mr. T. Smith asked if any of the conclusions of the theory would be modified if we were assumed to be the dealing with group velocities rather than wave velocities. If he remembered rightly the most accurate determinations had revealed a difference even in vacuum. Professor Eddington was unable to say off-hand. Dr. E. H. Rayner asked what happened if the velocity of a body exceeded the velocity of light. Professor Eddington pointed out that a body would require infinite energy to attain this velocity, and so could not exceed it.

THE SURVEYORS' INSTITUTION.—It has been decided, on the advice of the Reception Committee of the Somerset, Gloucester and North Wilts Branch, to hold the country meeting at Gloucester on July 8, 9 and 10, instead of June 10, 11 and 12, as was at first tentatively suggested. The council have for some time been considering the desirability of promoting legislation for the registration of the profession. They recognise that there are difficulties in the way owing to the many demands upon the time of Parliament ; there is also the fact that a certain amount of overlapping exists in the various professions. It seems possible, however, that these difficulties might be overcome by joint action.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Vickers, Limited.—The electrical works of this company are full of orders, and present prospects are reported to be excellent. Sheffield will share in the benefit, as certain sections of material are to be made here. Messrs. Vickers' Barrow works have been extremely busy with shipbuilding, and expect to continue so for some time ahead. Contracts for a term of years have been made with the Cunard and other companies. A large number of oil tankers fitted with internal combustion engines of the firm's own type is being built at Barrow. At the same place a large number of locomotive engines is being reboilered and repaired. Vickers Crayford works are increasing their output of sewing machines satisfactorily and are manufacturing standard motor-car parts for the Wolseley Company. Vickers' works at Ipswich are now devoted to the manufacture of medium-sized internal-combustion engines.

Iron and Steel.—Engineering masters report a somewhat quieter demand for certain classes of heavy products, due to increased prices at home, but more particularly to the diminished value of Continental currency, chiefly in France and Italy. Thus, though it has attracted a large number of new customers by substituting machinery manufacture for that of armaments, one of Sheffield's largest steel firms to-day employs locally, and at subsidiary concerns elsewhere, only 44,000 people, as compared with 107,000 during the war. Information is to hand that some of the French engineering firms, being unable to afford the current record price for Sheffield steel and machinery owing to the decline of the franc, are turning for relief to German sources, but without securing appreciable satisfaction. For the moment, demand for crucible steel for shipment is at rather a lower level, though furnaces have recently booked sufficient orders to keep them fully engaged for some little time ahead. File-makers, too, are beginning to find weak patches in the requirements of engineering firms, though this is attributed more to the release of Government stocks than to change in the volume of consumption. An interesting feature of the current steel position is the amalgamation of seven medium-sized concerns with the object of adjusting distribution and minimising costs. In contrast with the easement in other sections, the demand on output of steel sheets, hoops, strip and boiler plates is extraordinarily brisk. Scarcity of basic steel is one of the most unsatisfactory features of present-day working.

South Yorkshire Coal Trade.—Though there seems to have been an improvement during the past week, outputs at the South Yorkshire pits since the holidays have been far from satisfactory. Manufacturers in the heavy trades are complaining generally of shortage of supplies, and have made serious inroads in the emergency stocks in order to maintain production. Cobbles, nuts and slacks are all condemned day by day on contract and controlled account. Rumours of an immediate increase in the price of household fuel have caused a further influx of orders. Merchants have heavy arrears to wipe off. Maximum prices are easily obtainable for all classes of coke. Quotations :—Best branch handpicked, 23*s.* to 24*s.* ; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.* ; Derbyshire best brights, 21*s.* to 22*s.* ; Derbyshire house coal, 18*s.* 6*d.* to 19*s.* 6*d.* ; Derbyshire best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.* ; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.* ; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.* ; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.* ; rough slacks, 24*s.* to 25*s.* ; nutty, 23*s.* to 24*s.* ; smalls, 19*s.* to 20*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

Cleveland Iron.—Quotations for Cleveland pig-iron are unchanged, but this is of no consequence as contracts now contain a clause to the effect that the iron is sold at the price ruling at the time of delivery. Producers will not sell except on this condition. A feeling prevails that prices will have to be again moved up to cover the still rising cost of manufacture. The latest addition to cost of output is a rise in the price of limestone. For home consumption, No. 1 Cleveland pig-iron is 212*s.* 6*d.* and No. 3 and the lower qualities are 200*s.* ; while for shipment to France, Belgium and Italy No. 1 is 217*s.* 6*d.* and No. 3 and the commoner kinds are 205*s.*

Hematite Iron.—So far as East Coast hematite is concerned, makers admit that adverse rate of exchange rather restricts business with Continental customers, but they report a ready market for all they can manufacture. They are very well placed, and in no great hurry to book further orders. No. 1 is 262*s.* 6*d.*, and mixed Nos. are 260*s.* for home purposes ; and the quotations are 267*s.* 6*d.* and 265*s.* respectively for export to France, Belgium and Italy.

Foreign Ore.—A distinctly easy feeling is noticeable in foreign ore. Consumers are now carrying considerable stocks, and are not at all eager to make further contracts. Further sales, however, have occurred on the basis of 49*s.* for rubio, of 50 per cent. quality, on the 17*s.* parity freight, Bilbao-Middlesbrough, which reduces the ex-ship Tees value of best rubio to 62*s.* 6*d.*, as the freight from the Spanish port has fallen to 30*s.* 6*d.*

Coke.—While scarcity of coke is much less acute than it has been, supply is still far from ample. Average blast-furnace quality is 55*s.* 6*d.* at the ovens, low phosphorus sort is 58*s.* at the ovens, and foundry description is 63*s.* for home purposes.

Manufactured Iron and Steel.—Little new, of moment, is ascertainable concerning finished iron ore and steel. Few manufacturers are in a position to entertain business

offering, as they have heavy order books and are considerably in arrears with deliveries. Stocks of steel are still accumulating and now approach 100,000 tons. Customers continue to clamour for supplies in fulfilment of contracts made, but, unfortunately, owing to lack of transport facilities, these huge stocks cannot be distributed. Values of all descriptions are very firm and bars and rivets have advanced. Common iron bars are 28*l.*; marked bars, 30*l.*; steel ship, bridge and tank plates, 22*l.*; angles, 21*l.* 10*s.*; rivets, 36*l.*; steel boiler plates, 28*l.* 10*s.*; steel joists, 21*l.* 10*s.*; packing steel (parallel), 18*l.* 5*s.*; packing steel (tapered), 22*l.* 10*s.*; steel strip, 27*l.* 10*s.*; steel hoops, 27*l.* 10*s.*; soft steel billets, 22*l.* 10*s.*; hard steel billets, 23*l.* 10*s.*; heavy sections of steel rails, 23*l.*; fishplates and sleepers, 28*l.*; black sheets, 45*l.*; and galvanised corrugated sheets, 56*l.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

State of Trade.—The state of trade in general throughout the country is still of pronounced activity in practically all branches of industry, and there can be no fear of collapse for some considerable time to come. The ever advancing prices will ultimately have some effect upon buying, and the actual consumer, who has to bear the burden finally, will lessen his demands as present prices are getting prohibitive. So far there has been no falling-off, and as much stuff as can be turned out is eagerly snapped up for local requirements, while the general export trade is only a ghost of its former self. Prices of everything will mark another forward step, owing to the rise in fuel caused by the increases in wages to the miners and the new Government demands. Already the makers of bar iron have added another 40*s.* per ton to their prices, and one thing after another will most probably follow suit. Employment over all is quite good, and the latest statement of the Engineers' Society shows a reduction in the number of men unemployed.

Scotch Steel Trade.—Little change of any kind falls to be recorded in the steel trade of Scotland, and the old cry, more work than can be conveniently tackled, still prevails. Through certain circumstances over which the masters have no control, the output is not as large as they would like and falls far short of present-day requirements. The demand continues on an unprecedented scale and consumers are continually pressing for deliveries of both plates and sections, &c. The black sheet makers are finding it no little matter to keep all their customers satisfied, and indeed many of the latter are only kept moving along from day to day and the uncertainty of supplies is harassing them considerably. The booking of new business is small for the simple reason that makers' order books are so full for months to come that they consider further commitments to any extent would be injudicious. The shipping side of the steel industry is of little consequence, yet as the home market is so hungry for material and no improvement is expected in the meantime. Prices are very firm, but have not changed.

Malleable Iron Trade.—About the only item of note in the malleable iron trade of the West of Scotland this week is another advance in prices amounting to 2*l.* per ton. The bar-iron makers have found this necessary owing to the rise in raw materials—pig-iron, scrap, &c. The minimum selling price of "crown" bars is now 28*l.* per ton at Glasgow station, and extras have also been raised in some cases by over 100 per cent. Orders are plentiful and the works are all busy, a state which is ensured for some time owing to recent heavy bookings.

Scotch Pig-Iron Trade.—Conditions in the Scotch pig-iron trade show little change during the week, and all kinds of iron are extremely scarce, and it is impossible to secure almost anything for prompt delivery. The home consumers are having difficulty on account of the limitations put on supplies which are being spread over as many as possible, and the export business is still on the small side. Prices are strong, and notwithstanding their present high level it is fully anticipated that they will be further advanced shortly. The following may be taken as current quotations: No. 1 foundry iron, 16*l.* 5*s.* per ton; and No. 3 foundry iron, 15*l.* 10*s.* per ton, f.o.b. Glasgow. Hematite is in large demand by steel makers and deliveries are not long in being used up.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—Conditions on the coal market show little change because of the continued scarcity of coals available for foreign shipment as a result of the pressure for home supplies. Releases have, however, been more freely granted of late for British coaling stations abroad and Italy, but for other directions the endorsement of pre-entries are as difficult to secure as ever. Meanwhile the docks are congested with shipping, in addition to which there are also a large number of vessels in the roads waiting cargoes. The outlook, too, is none too promising, though there is a possibility of a relaxation in inland requirements as it should only be necessary in the immediate future to keep stocks up, as large quantities have been despatched both by rail and sea to home consumers during the past couple of months. Exports of coal foreignwise last week amounted to 331,623 tons, of which 191,696 tons were despatched from Cardiff, 52,612 tons from Swansea, 53,750 tons from Newport and 33,535 tons from Port Talbot. France, as usual, received the largest proportion of exports with 216,661 tons, equal to 65 per cent. of the total; Italy, 37,746 tons; South America, 8,789 tons; Spain, 15,051 tons; Portugal, 8,727 tons; British coaling stations, 40,367 tons; and other countries, 4,282 tons. New business is very difficult as collieries in practically all cases are full up with allocations and contract commitments and, therefore, have little coal for disposal on the open market. For the odd quantities available they have no difficulty in securing 115*s.* for large, 105*s.* to 107*s.* 6*d.* for throughs and 92*s.* 6*d.* to 97*s.* 6*d.* for smalls. Business in coke remains at a standstill owing to the continuance of the export embargo, while patent fuel is practically unobtainable as makers are full up with contract commitments. For the small parcels available 125*s.* to 130*s.* is firmly demanded and paid.

Iron and Steel Trades.—A number of claims have been submitted by the Dockers' Union section of the Tinplate Joint Industrial Council and included amongst these is a demand for a 100 per cent. advance in the base wage rate. The idea is understood to meet the possibility of the employers withdrawing the whole or part of war bonuses, in which case the doubling of base wage rates would affect subsequent percentages. In view of these claims, sellers' refuse to ease quotations, especially for forward business, as costs of production are increasing, and for standard boxes 72*s.* 6*d.* to 76*s.* is firmly quoted. There is a steady demand for galvanised sheets on the basis of 56*l.* for 24-gauge corrugateds, while steel bars range from 30*l.* to 32*l.*

IMPERIAL WAR MUSEUM, CRYSTAL PALACE.—On June 9, the King, accompanied by the Queen and the Chief Officers of State, will open at the Crystal Palace the Imperial War Museum, to which is attached the Great Victory Exhibition. H.M. Office of Works have taken the whole of the main floor for naval, military and aircraft exhibits. A very important section of the exhibition will be that devoted to the oil exhibits. There are to be a large number of working models which will provide an exhibition of the various branches and possibilities of the oil industry. In addition the sections comprising electricity, engineering and gas will have a commanding interest, and the public will have an opportunity of learning how knowledge gained in the science of war can be applied to the progressive achievements of peace.

METALLIC VESSELS FOR THE TRANSPORT OF LIQUID AIR.—The detailed account of a research, conducted at Leipzig University during the war by F. Banneitz, G. Rhein and B. Kurze (*Annalen der Physik*, vol. lxi, pages 113 to 144, January 15, 1920) for the purpose of constructing vacuum-jacketed vessels, not of glass, which is brittle, nor of copper, which was too scarce, but if possible, of a cheap metal like iron, does not add much to our knowledge. Originally most of the German containers for liquid air were made by the firm of Burger, of Berlin, in silvered glass. Then Ahrendt succeeded in manufacturing very good vessels of two concentric spheres of brass or copper; the vacuum in the space between the two shells was not perfect, but was improved by placing charcoal in this space. Such vessels lost 0·029 kg. or 0·034 kg. of liquid air per square decimetre per day, against 0·023 kg. in the Burger vessels. Banneitz tried celluloid in sheet 3 mm. thick, but it was too brittle when cold. Nickel and copper have both been used (before the war) by Lilienfeld. The trouble with some metals is that they contain gases, and to get rid of these, the metals have to be heated to fairly high temperature. They are also easily heated by Foucault currents and they radiate heat. Iron has to be heated to at least 300 deg. C. for primary evacuation, and has to be silvered to avoid the radiation; this silvering cannot be done by a spray process, as the silver film is not sufficiently adherent and smooth, but has to be applied galvanically. They made also three-walled vessels, the intermediate iron wall, silvered on both sides, acting as a screen to prevent radiation, as suggested by O. Wiener, and in these vessels they brought the losses of liquid air down to 0·075 kg., whilst the loss was 0·6 kg. in two-walled, not silvered iron vessels. Tin was to be tried, but it was unobtainable during the war.

AMERICAN TRADE WITH RUSSIA.—After consideration of the question of trade with Russia, the Board of Directors of the American Manufacturers' Export Association, New York, has, according to *The Iron Age*, passed resolutions warning its members to exercise great caution in the impending trade relations with the Soviet Government. These resolutions, however, point out that the members of the association are desirous of resuming commercial intercourse with the Russian people when they are under a form of government of their own selection. The following resolutions were passed: "Whereas there are many exaggerated reports in regard to the amount of trading transactions which can be carried on between Russia and the outside world; and whereas under any circumstances due to the breakdown of the Russian transportation system there can be only a relatively small amount of business transactions on the basis of an exchange of raw materials for manufactured goods; in view, further, of the published statement of the so-called Soviet Government in Russia it is evident that trade with Russia is practically impossible, except under the direct supervision and control of this Government; it has been resolved that the American Manufacturer's Export Association warns its members and other manufacturers to exercise the greatest care and caution against impending trade relations with Russia under the present Soviet Government; and it has been further resolved that the members of the American Manufacturers Export Association are eager and desirous of resuming commercial intercourse with Russia and the Russian people when that country is under some form of government of its own selection, a government which has been chosen by a properly elected assembly."

NOTICES OF MEETINGS.

THE LONDON ASSOCIATION OF FOREMEN ENGINEERS.—Saturday, May 1, at 6 p.m., at Cannon-street Hotel, London, E.C. Sixty-seventh Anniversary Festival. T. O. M. Sopwith, C.B.E., in the chair.

THE SOCIETY OF ENGINEERS.—Monday, May 3, at 5.30 p.m., Meeting in the Rooms of the Geological Society, Burlington House, W. (entrance at the east end of the building in Piccadilly). Social gathering at 5 p.m. Paper at 5.30 p.m., on "The Assessment of Engineering Undertakings," by Mr. W. G. Cooke, A.R.I.B.A., Assoc.Inst.C.E., Member of Council.

THE ROYAL SOCIETY OF ARTS.—Monday, May 3, at 8 p.m.: Cantor Lecture, "The Decoration and Architecture of Robert Adam and Sir John Soane, 1758–1837," by Mr. Arthur Thomas Bolton, F.R.I.B.A., F.S.A., Curator, Soane Museum (Lecture I). Wednesday, May 5, at 4.30 p.m.: Ordinary Meeting. "A Photographic Research Laboratory," by Mr. C. E. Kenneth Mees, D.Sc., F.C.S. Sir Henry Trueman Wood, M.A., Vice-President and Chairman of the Council, will preside.

THE RÖNTGEN SOCIETY.—Tuesday, May 4, at 8.15 p.m., Special General Meeting at the Rooms of the Medical Society of London, 11, Chandos-street, Cavendish square W. Paper on "Some Problems in the Action of Radiation upon Tissues," by the President. Demonstrations: "The Transmission of Speech by Light," by Professor A. O. Rankine, O.B.E., D.Sc.; "New Portable Viewing Lantern," by Dr. H. A. Eccles.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS—(LONDON).—Tuesday, May 4, at 7 p.m., Meeting in Room No. 18, Caxton Hall, a paper by Mr. J. W. Dow, Member, York, on "Lubrication" will be read and discussed.

THE IRON AND STEEL INSTITUTE.—Thursday and Friday, May 6 and 7, Annual Meeting at the Institution of Civil Engineers, Great George-street, Westminster, commencing each day at 10 a.m.; the meeting to be adjourned from Friday, May 7, to Friday, May 14, when a final session will be held at the Mappin Hall, Sheffield, commencing at 3 p.m. Thursday, May 6: 10 a.m., General Meeting of Members; the Council will present their Report for the year 1919; the retiring President (Mr. Eugène Schneider) will induct into the chair the President-elect (Dr. J. E. Stead, F.R.S.); the Bessemer Gold Medal for 1920 will be presented to Mr. Harry Brearley (Sheffield); the award of the Gold Medal and Freedom of the Blacksmiths' Company will be announced; the President will deliver his Inaugural Address; a selection of papers will be read and discussed (No. 6). 2.30 p.m., Afternoon Session (papers Nos. 3, 11, 8, 4). 7 p.m., Annual Dinner of the Institute in the Grand Hall of the Connaught Rooms, Great Queen-street, W.C. Friday, May 7: 10 a.m., General Meeting of Members; a selection of papers will be read and discussed (Nos. 1, 10, 12). 2.30 p.m., Afternoon Session (papers Nos. 5, 2, 9, 7). The following is a list of the papers which it is expected will be submitted at the London meeting: Presidential Address; (1) Mr. C. A. Ablett, "Direct Current compared with Three-Phase Current for Driving Steel Works Plant"; (2) Mr. T. Baker and Mr. T. F. Russell, "Note on the Ball Test"; (3) Mr. F. Clements, "British Blast Furnace Practice"; (4) Mr. J. A. Heskett, "The Utilisation of Titaniferous Iron Ore in New Zealand"; (5) Mr. W. E. Hughes, "Some Defects in Electro-deposited Iron"; (6) Mr. E. H. Lewis: "Iron Portland Cement"; (7) Mr. G. F. Preston, "Practical Notes on the Design and Treatment of Steel Castings"; (8) Mr. C. H. Ridsdale, "The Valuation of Ores and Iron-making Material"; (9) Mr. J. H. Whiteley, "The Distribution of Phosphorus in Steel between Points Ac1 and Ac3"; (10) Mr. J. F. Wilson, "Notes on Slag Conditions in Open-Hearth Basic Steel-making Practice"; (11) Mr. H. E. Wright: "Chemical and Thermal Conditions in Blast Furnace Practice"; (12) Mr. B. Yaneske and Mr. G. A. Wood: "The Reduction of Silicon from the Slag in the Acid Open-Hearth Process." The following is a list of the papers which it is expected will be submitted at the Sheffield Meeting: (13) Mr. J. H. Andrew, Mr. J. E. Rippon, Mr. C. P. Miller and Mr. A. Wragg, "Effect of Initial Temperature upon the Physical Properties of Steel"; (14) Mr. C. A. Edwards, Mr. H. Sutton and Mr. G. Oishi, "The Properties of Iron-Chromium-Carbon Steels," Part I, "Thermal Analysis"; Mr. C. A. Edwards and Mr. A. L. Norbury, "The Properties of Iron-Chromium-Carbon Steels," Part II, "Effect of Heat Treatment on Electrical Resistivity"; (15) Mr. K. Honda and Mr. T. Murakami, "On the Structural Constitution, Hardening and Tempering of High-Speed Steel containing Chromium and Tungsten"; (16) Mr. J. H. G. Monypenny, "The Structure of some Chromium Steels"; (17) Mr. A. L. Norbury, "The Effect of various Elements on the Electrical Resistivity of Iron"; (18) Mr. F. Rogers, "Brittleness of Nickel-Chrome and other Steels," Part II.

THE BIRMINGHAM METALLURGICAL SOCIETY.—Thursday, May 6, at 7 p.m., at the Birmingham Chamber of Commerce, New-street. Paper by Mr. A. Forshaw, M.Sc., "Gas-Fired Furnaces."

INSTITUTE OF INDUSTRIAL ADMINISTRATION.—The Institute of Industrial Administration, 110, Victoria-street, S.W. 1, held their first general meeting at the Central Hall, Westminster, on Tuesday, 27th inst., 150 members attending. The hon. secretary announced very wide support from both London and the Provinces, and also a promise by Lord Haldane to address the members on the subject of administration. A strong Provisional Committee was appointed, representing many branches of industry. As an immediate step in the work of the Institute, a series of lectures on the "Organisation of Payment by Results" will be given at the Central Hall, Westminster, commencing Thursday, May 6.

ARMSTRONG SHIPYARD: KEEL PLATE FLANGER AND HYDRAULIC RIVETERS.

(*For Description, see Page 567.*)

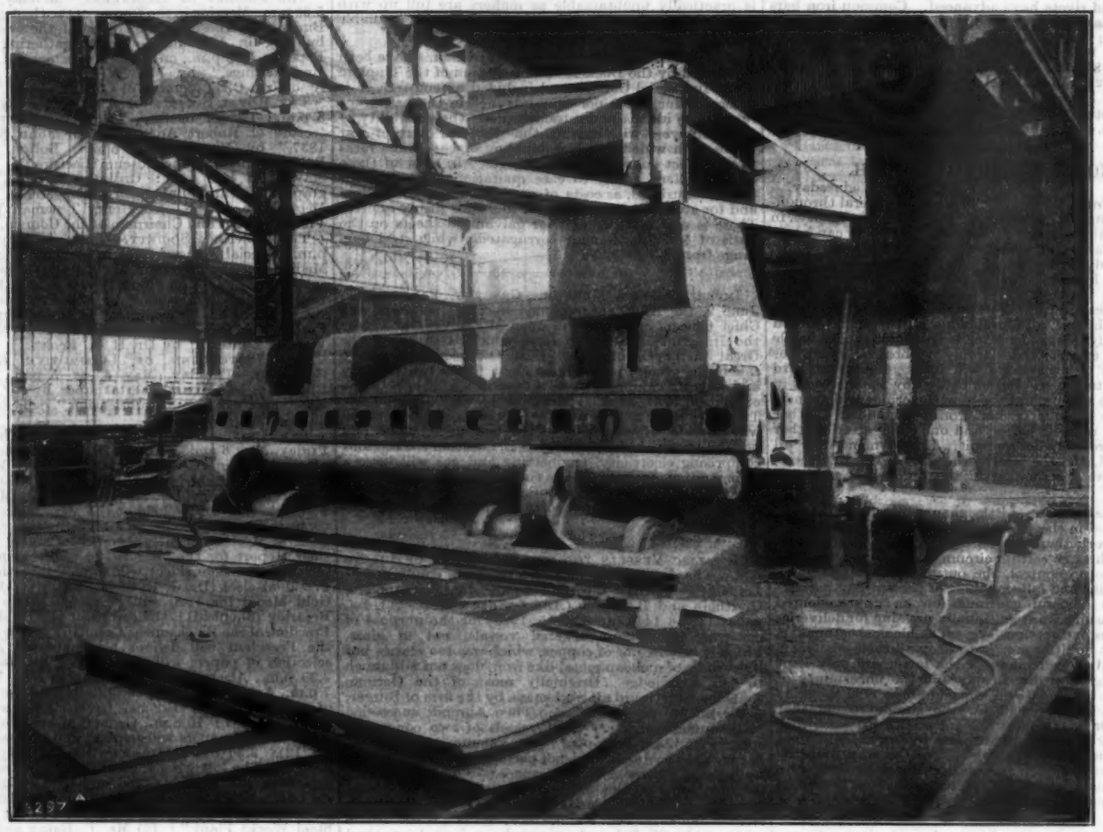


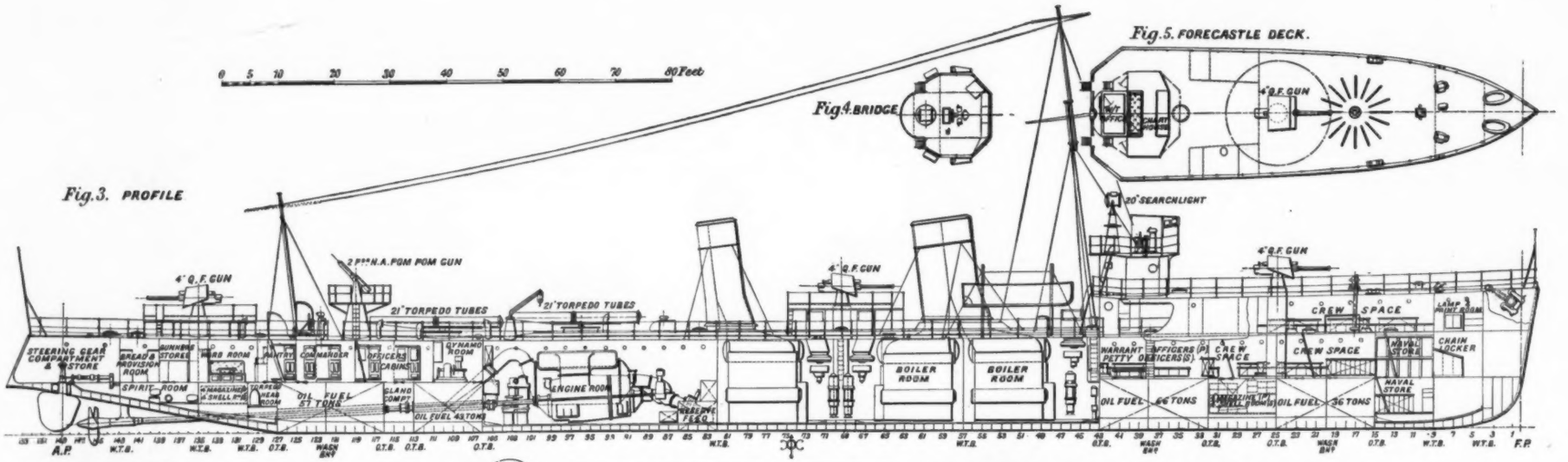
FIG. 133. KEEL PLATE FLANGING MACHINE IN PLATERS' SHED.

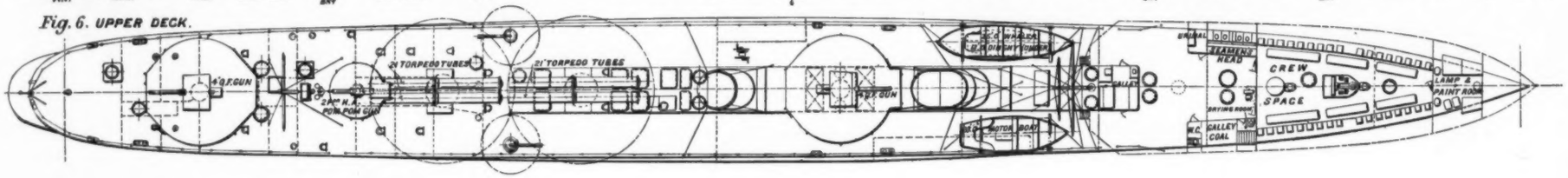
FIG. 134. HYDRAULIC RIVETING PLANT IN YARD

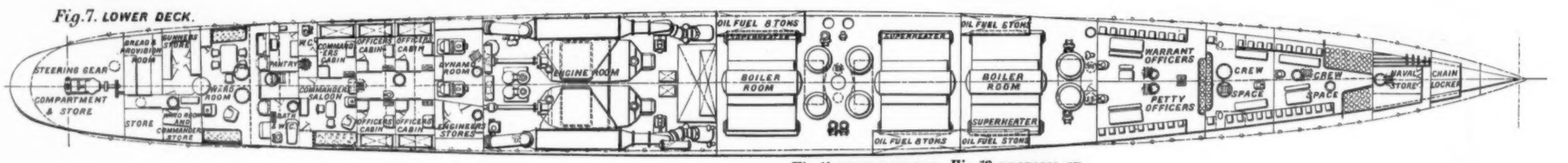
TYPES OF HIGH-SPEED WAR CRAFT.

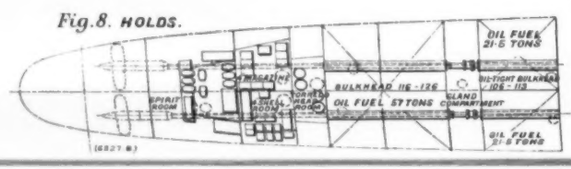
CONSTRUCTED BY MESSRS. YARROW AND CO., ENGINEERS, SCOTSTOUN, GLASGOW.

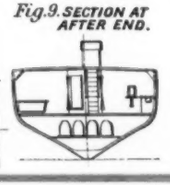
(*For Description, see Page* 578.)

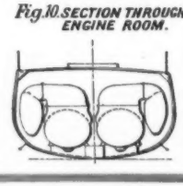


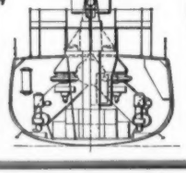


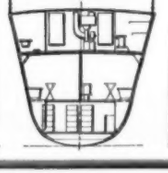


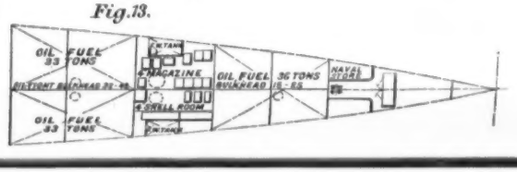












FIGS. 3 TO 13. OCEAN-GOING TORPEDO-BOAT DESTROYER.

FIGS. 3 TO 13. OCEAN-GOING TORPEDO-BOAT DESTROYER.

Fig. 14. PROFILE.

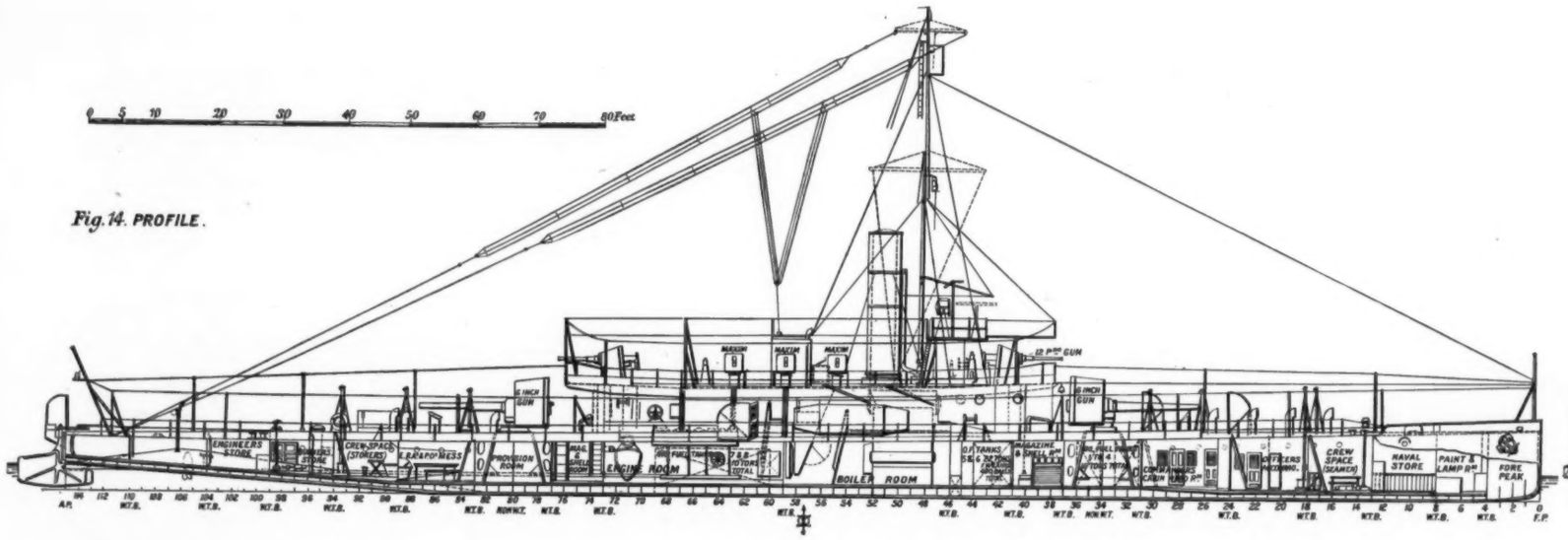


Fig. 15. DECK PLAN.

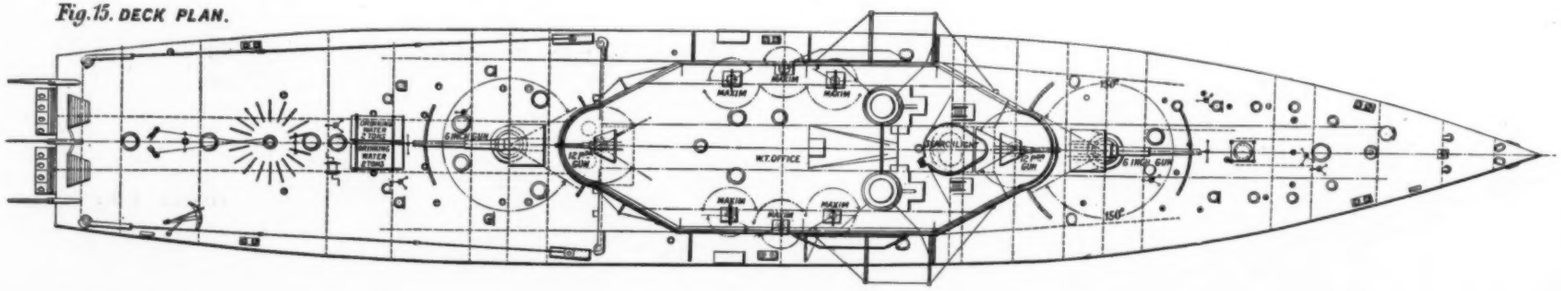


Fig. 16. HOLDS.

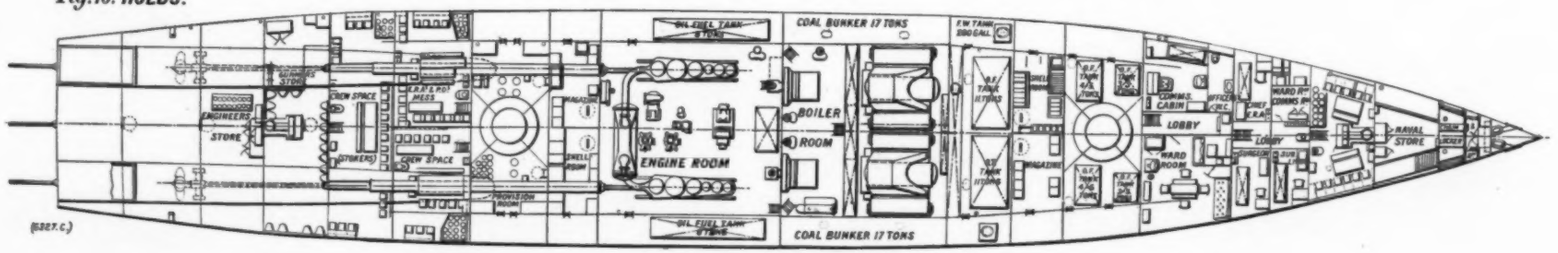


Fig. 17. SECTION ABOUT FRAME 52, LOOKING FOR'D.

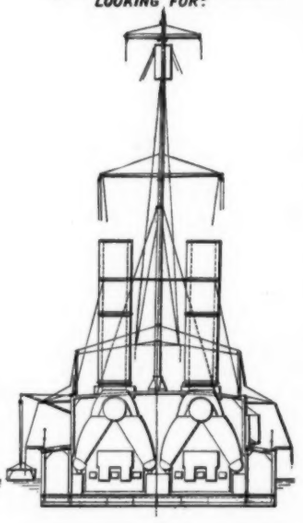
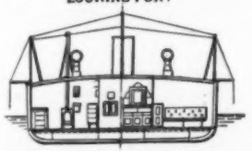


Fig. 18. SECTION ABOUT FRAME 71 LOOKING FOR'D.

Fig. 19. SECTION ABOUT FRAME 27 LOOKING FOR'D.



FIGS. 14 TO 19. LARGE GUNBOATS FOR THE TIGRIS.

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With a Two-Page Plate of the TYPES OF HIGH-SPEED WAR CRAFT.

NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s. 2d. per copy, and this price dated from and included the issue of Friday, April 2, 1920. So long as postal rates remain as at present there will be no increase in the price of copies sent by inland post, which will continue at 1s. 2d. post free.

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In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 581.

ENGINEERING.

FRIDAY, APRIL 30, 1920.

FARM MACHINERY.

NOTWITHSTANDING the great importance and undoubted energy of our leading firms manufacturing agricultural machinery the engineer, as yet, hardly appears to hold the place he should in agriculture. It is the oldest, or one of the oldest, of industries and has always been dependent to some extent on engineering; yet, nowaday, the engineer's activities in connection with it are proportionately smaller than in many other branches of work. This is possibly because of its age. The newer a branch of activity the more engineers appear to have to do with it. Aerial travel is all engineering, and transport is mostly engineering. A more primitive type of activity such as cooking, which we understand is the hall mark of civilisation, is perhaps 25 per cent. engineering. Some trouble and doubtful profit would ensue were one to attempt to estimate the engineering content of every branch of human activity, but the idea that the newer an industry the more it is an engineer's matter probably has something in it. Coming to husbandry, which is our present concern, and which may possibly be classed with cooking in its antiquity, we hesitate to assign a figure representing the extent to which engineering is concerned in it, but there is no doubt but that both from the point of view of the engineering profession and that of agriculture itself the proportion might profitably be increased.

Many things have retarded the application of engineering to farming, especially in this country. The last few years have, of course, been exceptional, but previous to them for a long period the industry had been far from prosperous, and many farmers certainly had no money to spare for expenditure on machinery. The freeholder too was not very common, and a tenant farmer might hesitate to purchase appliances which he could not be sure would be suitable for another farm to which he might have to move later. Another factor retarding the introduction of machinery was that labour was cheap, and unless a financial case could be made out for the introduction of a farm machine there was no reason why a farmer having no engineering predilections should concern himself with it. These factors were probably the determining causes in the present position of agricultural machinery, although one must add to them the effect of the factor to which we first referred, the natural conservatism existing in an ancient industry.

The war and the end of the war have opened a new phase in British farming. A general shortage of cereals has resulted in enormously better prices ruling for a farmer's produce, but to balance this the cost of his labour and general supplies has risen correspondingly, or perhaps rather more than correspondingly. This should apparently be the engineer's opportunity. In farming as in other matters the way to deal with high wages is to increase the output per employee by improving methods, which, to a very large extent, means the introduction of machinery. Farming, however, is not altogether on a parallel with motor car manufacturing. It cannot be concentrated in one place, and cannot to any considerable extent be specialised, at any rate in this country. The essentially scattered nature of the industry also makes it difficult for the best information relative to the employment of machinery to be conveyed to any considerable proportion of the people concerned. There is also in farming a difficulty somewhat analogous to the present limitation of our railway loading gauge which makes it difficult, or impossible, to take full advantage of the best which is known in railway engineering. This difficulty lies in the small and irregular fields in which so many of our farms are laid out and the narrow lanes and gateways leading to them. The present tendency in the direction of the creation of small holdings, however desirable, in other respects, will not tend to lessen this difficulty. It is a retrograde movement as far as the improvement of efficiency by the greater application of machinery to farming is concerned.

As the engineer is certainly wanted to a greater extent on the farm, an enquiry into the difficulties in the way and recommendations for their amelioration are timely and practical proceedings. This work has recently been carried out by a Committee appointed by the President of the Board of Agriculture. The Committee's report* has just been published. On the whole, it is disappointing, but we do not know that it could well have been anything else. We fear no committee could evolve a scheme to work any magic in British farming. The recommendations are humdrum, but could hardly profitably have been otherwise. Conditions will not be improved except by the natural pressure of economic conditions and by such assistance as may be given by the spread of education and information. The Committee recommends research, standardisation, testing, trials, education and propaganda.

Research we will refer to in a moment. Standardisation is a matter obviously calling for development. In the course of the enquiry on which the report is based, Mr. Courtney, the consulting engineer to the Royal Agricultural Society, stated that one plough manufacturer alone had over 250 patterns of plough and that there were over 1,000 types of plough in the country. The question of reducing this number is naturally to some extent bound up with the matter of research, but it is impossible to suppose that more than a small fraction of these types is really necessary. The trade amalgamations which are taking place among agricultural machinery manufacturers may be expected to have some influence on this matter, but some concerted action involving the whole trade is certainly desirable. This applies particularly to small parts. If a farmer could always replace a minor breakage from the agent's shop in the nearest town by a duplicate which would fit any make of machine it would help considerably in the increase in the use of such machines. This matter is mainly in the hands of the manufacturers, and something is apparently already being done. Mr. H. G. Burford stated that the tractor trade had a committee which was considering the standardisation of certain tractor parts.

On the question of testing and trials, the Committee recommends that a Central Advisory Committee should be set up by the Ministry of Agriculture. This Committee would consist of representatives of the various interests concerned. It would carry out very complete tests of any type of agricultural machine, and it is suggested that for the present the work should be done on farms attached to agricultural institutions, although it is considered that a special testing station might be necessary later. These tests are intended to be of a very thorough nature, and it is suggested that a tractor might be under continuous test for a year and a threshing machine for six months. What is proposed is evidently a very different sort of thing from the type of trial carried out by the Royal Agricultural Society. This kind of competitive trial clearly has certain defects. Owing to its brevity, the element of luck must enter largely into it.

* Report of the Departmental Committee on Agricultural Machinery. [Cd. 566.] 1s. net.

The recent trials by the Society of Motor Manufacturers and Traders at Lincoln were organised to exclude some of the features of the Royal Society trials, but even with them the defect of brevity remained. Clearly, a test, something on the lines of the trials of motor vehicles carried out by the Royal Automobile Club would be an improvement on anything we now have, and the proposals of the Report would ensure this. Testing institutions somewhat of the class suggested by the Committee are in operation in other countries, and particularly in Sweden, and their work has been attended with great success. The advance of the Swedish dairy machinery industry is attributed by the Committee largely to the effect of the official testing station.

Education and propaganda we need not say very much about. That the spread of some elementary engineering knowledge among farmers and their labourers is very desirable, requires no arguing. A better standard of engineering information in the farming community would in itself do much to improve the efficiency of operation of farm machinery and to extend its use. It is proposed that education authorities should be encouraged to provide local instruction in agricultural machinery, and that the subject should be given more attention in agricultural colleges and farm institutes. Apparently, machinery is now looked upon very much as a side line in most of these establishments, but in view of its potential and actual importance it is to be hoped that the Committee's recommendation may bear fruit. There is probably a difficulty in obtaining teachers qualified in both farming and mechanism, but the institution of a demand would probably in a few years result in a supply. In connection with this matter, it is interesting to note that witnesses disagreed as to the best type of training for such instructors. Some thought he should be an agriculturist who later spent time at an engineering works, and others that he should be an engineer who later acquired a knowledge of agriculture. This is quite new matter to add to the old controversy about the training of an engineer.

The final matter to which we wish to refer is research, and in approaching it, it may be well to emphasise that the subject concerned is not research in agriculture, but research in agricultural machinery. The Committee's finding on this matter were clearly coloured by the interesting evidence given by Dr. E. J. Russell, of Rothamsted. Dr. Russell's thesis briefly was that the whole subject of cultivation was at present in an empirical state, and that the real physical effects which were aimed at in working the soil were unknown. He considered that cultivation now was in the same state that manuring was in 1840. At the present time the scientific basis of manuring was laid down, but the science of cultivation was non-existent. The Committee was evidently much impressed with the idea underlying this evidence; and we are not sure that they did not let it run away with them. They express an "emphatic opinion that every effort should be made to place agricultural engineering upon a scientific basis with as little delay as possible." They regard a reform in the methods pursued as overdue, but "do not intend to express or imply any strictures upon those who, whether as manufacturers or investigators, have been engaged in dealing with the subject." This is really very considerate.

May we suggest to this Committee, and also with all deference to Dr. Russell, that all physical science is coordinated empiricism. Dr. Russell says that manuring is now scientific, but in what does a parallel test with, say, the effect of nitrate of soda, sulphate of ammonia and nitrolim on the growth of a certain crop at Rothamsted differ from empiricism? If one wanted to test two ploughs, one might in the same way plough similar fields with each and sow similar crops. The result would give some measure of suitability of the ploughs for the land dealt with, but why condemn this as empiricism and bless the parallel experiment with nitrogenous fertilisers as scientific? That more is known about manuring than about the physical basis of tilth we agree, and the work now being done by Dr. Russell should lead to interesting, and may lead to very valuable, results. That, on the whole, the advance of agricultural machinery must come from trial, experiment, empiricism, we hold, however, in spite of this Committee. If the results of such experiments can be coordinated, tabulated, organised and some general laws be deduced from them, let it be done by all means, and the Committee's recommendations for a Research Institute in Agricultural Machinery, together with the work of possible Industrial Research Associations, may forward this desirable end.

RAILWAY STATISTICS.

A START has recently been made in again collecting and publishing statistics relating to the railways of the United Kingdom. Such statistics were, of course, in abeyance during the war, and it is to the credit of the Ministry of Transport that, now that they have been resuscitated they appear in a more useful form than heretofore. As everyone knows, the defect from which the figures, formerly published, suffered, lay in the fact that tonnage, receipts and train miles were supposed to be a sufficient guide to a system's economical management. With the North-Eastern influence in the Ministry it is not surprising that the ton-mile has now been adopted. There are other statistics given which in course of time will prove of value, though at present they mean comparatively little. The value of such figures is, of course, comparative, and as there are no previous figures with which to compare those now issued, their immediate use is not great, though they will form the starting point for future investigations.

The present tables, which deal mainly with freight traffic and the service of locomotives and wagons, are published in the form of a foolscap return of some 50 pages. We are further promised similar statistics for passenger traffic, and others relating to maintenance of permanent way, rolling-stock and so on. When all these are in existence the return will be a fairly large one, and it is very questionable whether it is really necessary to make so much information available monthly. The purpose would probably be equally well served by circulating some of it among the railways monthly and publishing the complete return half-yearly, or even annually. The price of the present return is already 1s. 6d.; as we have indicated, the complete return will be much larger.

We may pick out a few of the figures now published as samples to give an idea of the information the new tables contain, this being of a much more varied character than anything hitherto available for general use, whatever figures may have been at the command of individual managers. For instance, the average freight train load for Great Britain is 132·38 tons. The highest loading figure is to the credit of the Great Central, which averages 174·15 tons, while the lowest is recorded against the London Brighton and South Coast with 88·75 tons. The heavy mineral traffic of the Great Central probably contributes to its high figure, though rather curiously the average haul for coal, &c., is not conspicuously high on this line, amounting only to 33·15 miles. The longest average haul for coal is on the Great Eastern, as might be expected.

In tables showing the number of train-miles run per train-hour the London and South-Western Railway occupies a unique position. Against the average for passenger traffic for all railways in Great Britain of 13·1 train-miles per train-hour, the London and South-Western shows 22·9, only two others being much above 13. In freight service the average is 7·29, the London and South-Western figure is 16·28, and none of the other English lines reach even double figures. This unit represents the total train miles (loaded, empty, and engine and brake) divided by engine train-hours in traffic. As the London and South-Western statistics do not appear to conform yet to the full returns asked for by the Ministry, there may be some discrepancy in this which will be adjusted later. This Company's records indicate that no less than 36 per cent. of the total engine hours are occupied in shunting, and 27·3 per cent. in "other" work (such as assisting, light, &c.), while only 33 per cent. are "in traffic" train hours. This is an altogether abnormal allotment of time and possibly arises from some mode of computation not in line with those adopted by the other companies. It may be noticed that in coaching traffic the train-miles per engine-hour are also higher on this railway than on any other in Great Britain, though in freight traffic its figure is almost exactly the average.

In coaching traffic the shunting mileage should not be very great, though conditions may make empty mileage considerable at times. The Lancashire and Yorkshire Railway has booked against it the largest number of engine shunting miles in coaching traffic, viz., 14·77 per 100 train-miles, the lowest figure being for the London, Brighton and South Coast, with 5·57. In freight service again the same company stands highest with no less than 183·51 shunting miles per 100 train-miles, the Midland Company being at the other extreme with only 57·89. This figure is naturally dependent on the characteristics of the system, a complicated network such as the former company being much more likely to run into heavy shunting mileage than a trunk line. In traffic density measured by ton-miles per route mile the Midland system stands highest with the Great Central and Taff Vale systems next. These, it will be observed, are not the systems which have figured most prominently in the complaints of congestion.

THE DETERIORATION OF MATERIALS USED IN HARBOUR CONSTRUCTION.

THE inquiry inaugurated in 1916 by the Council of the Institution of Civil Engineers and approved by the Department of Scientific and Industrial Research into the effect of sea water and other influences on the materials used in construction deserves the earnest attention of all, who are responsible for the building and maintenance of docks and harbour works. The Institution has used its powerful resources to make the investigation thorough and exhaustive, and has set on foot inquiries in every quarter of the globe where commerce flourishes. At some 40 ports, in every variety of climate, engineers and port officials have been invited to place their accumulated experience and ripe knowledge at the service of the committee, and the response has been generous and unreserved.

As originally schemed, the intention of the Institution, or of the special committee appointed to conduct the research, was to undertake, in the first place, a series of experimental inquiries designed to provide information on obscure and doubtful points relating to the various causes of the damage sustained and as to the methods of combatting such damage. But owing to difficulties in obtaining both the necessary materials and the services of skilled assistants during the war, it was not found possible at the time to carry out this part of the programme. These experiments were not abandoned, however, but merely deferred, and at present, as we shall explain later, very comprehensive arrangements for their prosecution are being organised.

Under the circumstances just mentioned the Committee, of which Sir William Matthews is the Chairman, decided to commence their work by collecting detailed data as to the character of the damage to constructive materials experienced at a number of existing harbour works at home and abroad, and in response to their invitation a large number of valuable reports have been received on the destructive effects of sea water and sea organisms on timber, on the injuries to iron and steel where these materials have been used in structures, and on the deterioration of ordinary, and reinforced, concrete. The reports also include much detailed information bearing on the general character and scope of the research. These reports, after careful editing and revision, the committee decided to print, either in extenso or in an abridged form and the result is now before us in the form of an exceedingly valuable and interesting volume.* In those instances in which from con-

* *First Report of the Committee of the Institution of Civil Engineers, appointed to Investigate the Deterioration of Structures of Timber, Metal and Concrete, exposed to the Action of Sea Water.* Edited by P. M. CROSTHWAITE, B.A.I., M.Inst.C.E., Secretary to the Committee, and G. R. REDGRAVE, Assoc.Inst.C.E. Published by the Committee, Great George-street, S.W., and to be purchased from H.M. Stationery Office. [Price 30*s.* net.]

sideration of space, only extracts could be given, the original reports have been preserved in the archives of the Institution and are available for ready reference to those interested. Many of these reports were accompanied by specimens of timber and other materials that exhibited the effects of long exposure to sea action. These specimens, about 200 in number, are now open to inspection at the apartments of the Institution, where they form the nucleus of a museum which is calculated to become in the future of exceptional interest. The labelling and cataloguing of these exhibits have been carried out by Mr. Redgrave, and will afford valuable information to engineers engaged in the design and construction of sea and river works, both at home and abroad. This exhibition will be permanent and accretive, for it is intended that additions shall be made from time to time, as new materials are received from abroad and as the results of the committee's own experiments accumulate.

The above-mentioned reports, from which it is proposed to extract some of the more prominent conclusions, are in the volume before us, prefaced by several articles of considerable interest covering the ground that is considered in greater detail in special instances. Mr. Redgrave has collected the information published in the Proceedings of the Institution, which indicate the growth and extent of our knowledge on the subject generally. Mr. H. W. Fitz-Simons, in conjunction with Mr. F. T. Brooks, discusses the conditions that contribute to the value of timber as a material for marine structure. Dr. Cadman approaches the subject from the biological side and describes the structure and life habits of sea organisms. Owing to the interest of the subject, the same authority has arranged an exhibit in the Central Hall of the Natural History Museum, illustrating the natural history of marine and rock-boring animals, which should prove very instructive. Dr. J. Newton Friend submits a paper on the corrosion of iron and steel, a preliminary to further contributions which he proposes to offer in connection with the series of experiments that are in course of progress under the auspices of the committee.

These must be passed over with a very brief mention, but Mr. Redgrave's paper is of special interest as it describes the mechanical operations of the "teredo," known and dreaded by mariners from remote antiquity. The teredo or "ship worm" abounds in the tropics, where it will grow to an immense size; on a smaller scale it will live and flourish in the mild waters off our own coasts. This mollusc will penetrate into most kinds of timber, boring out tunnels or galleries, though naturally the more readily in the softer woods. The timber is entered by the young teredo through a minute pin hole, and entrance once effected, the hole is speedily enlarged as the mollusc increases in size and continually works further into the wood. It follows the direction of the grain, and passes upwards by preference. Why the teredo takes so much trouble is not very clear. It is believed to live on the infusoria and diatoms present in the sea water, and therefore apparently does not need for its sustenance the wood it removes. The minute particles of wood found in its body are regarded as being simply passed through, as the most ready and convenient way of getting rid of a waste product from a very confined space. The shells of the teredo, which are armed with minute teeth, furnish a tool for cutting away the timber, and the action in attacking the wood is rather that of a file than an augur. The tunnels are not bored out, but are rasped away by the rotary motion of the shell. Considerable method is exhibited in the process. Every teredo respects his neighbour's landmark. No one has been known to break through the thin wall of partition which separates two adjacent galleries. Though a pile be riddled with tunnels, each boring is entirely distinct. The Limnoria is a small crustacean that can be equally destructive with the teredo, with which it often works in friendly rivalry, the teredo confining its energies to the direction of the grain, the limnoria making its holes at right angles to the surface. The Limnoria knows no limits of latitude, it may be found in the Arctic Seas, and though no larger than a rice grain does its work very thoroughly. It bores out a hole only $\frac{1}{4}$ in. in length, but these holes are so close together that the whole surface of the timber is honeycombed, and speedily crumbles away under the action of the waves, leaving a fresh surface for attack. In a piece of wood 12 in. square, 54,000 perforations have been counted. Pitch pine logs to the depth of $\frac{1}{4}$ in. are carried away annually by this pest. At Hartlepool, where the North Eastern Railway Company have provided extensive timber ponds for the storage of imported logs, it is necessary to pump in fresh water, in order to reduce the salinity below a point at which the Limnoria can flourish. Other creatures, approaching shrimps and mussels, bore holes in wood and stone, inflicting an immense amount of injury. This spirit of mischief manifests itself even in monolithic masses of concrete.

The extensive use of iron and more recently of reinforced concrete in marine work has tended to restrict the losses occasioned by these creatures, and one of the objects of this inquiry is to determine the extent by which the more perishable materials may be replaced by others more reliable. It was not till 1865 that the value of concrete was recognised, and not till twenty years later that its use became general, and it was regarded as suitable for almost every kind of work in sea water. Long experience is therefore wanting: The test of time, which is of the essence of the problem, cannot be applied, and in much early work injudicious methods of use were employed. Experiment in actual practice has had to determine the most suitable size of block, the correct proportions of aggregate to cement, the amount of protective covering to be given to the steel to prevent the access of moisture, and many other variables have had to be decided on insufficient data. The problem of reinforced concrete now assumes a new aspect in consequence of its employment in shipbuilding. The conditions differ from those that obtain in the case of concrete simply immersed in the sea. The danger of mischief arising from electrolysis is greatly increased, for experiments have shown that though the electric current be feeble, if moisture is present the steel will rapidly become so coated with rust that disruption of the mass rapidly follows. The evidence of deterioration and the remedies suggested will be more conveniently considered when reference is made to specific cases.

Iron, cast or wrought, with steel as the demand for lightness of construction increased, has long been under observation and many tests have been made on its power to resist disintegration. The losses from corrosion in sea water under varying conditions of temperature, salinity, the introduction of sewage impurities and other causes have formed the subject of many inquiries, and the results have not always been consistent. Magnetism has been invoked as an operative cause to explain corrosive effects, but the charge has not been sustained. Electrolytic action set up by the contact of the iron with other metals can be a powerfully destructive agent, and the character of the reactions have not always been thoroughly apprehended. Dr. Friend puts the explanation very succinctly by saying that iron is preserved, if placed in contact with a more highly electro-positive metal, as zinc, but if in contact with a more highly electro-negative metal, the latter is preserved from oxidation at the expense of the iron. Zinc coating will make iron immune from corrosion as long as the zinc remains intact, but the zinc undergoes oxidation and requires repeated renewal. A difference of potential may arise from the employment in the same structure of iron or steel having slightly different chemical composition, for the addition of small quantities of alloying elements exercises a disproportionately great influence upon the physical and chemical properties of the metal. Such subtle differences are, of course, more difficult to detect. Much useful information has been drawn from unintentional experiments, as the recovery of iron objects long immersed in the sea, the consequence of accidents. Cannon balls and anchors fished up after being submerged for many years, have been found quite soft and capable of being cut with a knife, though exposure to the air may restore the original hardness. This phenomenon is due to partial conversion of the metal into ferrous oxide, the mass retaining the original shape of the metal. Here there is serious diminution in strength without any appreciable alteration in external appearance.

The process of destruction in building materials has to be learnt from its effects. In most instances the operating causes have to be conjectured in an uncertain fashion, and the devices designed to baffle or arrest decay must be regarded as experimental. It is not surprising therefore that structures reared under varying circumstances should differ in permanence; or that experts fixing attention on different details, should draw different conclusions wherewith to guide future action. Timber, considered as a building material, is especially wayward and uncertain, and offers many problems for which no solution has yet been discovered. Notwithstanding the length of time it has been under observation, the present position is the modest one of collecting evidence, the time for absolute prediction of results is not yet. Timber has some qualities not possessed by any other material used in construction—particularly the possibility of reproduction—but its variations in strength and texture, in longevity and uniformity of action are most puzzling. As it is a material very liable to decay, the discovery of a treatment that ensures successful preservation promises a great reward, but no certain preservative or means of resisting external attack under all circumstances has been discovered. The application of creosote in some form has been frequent, but the success is so uncertain, that the use of creosoted timber tends to decline rather than increase, and there is little inducement for further experiment. The committee state "that little or no change either in the character of the creosote itself, or its mode of application to timber with the view of rendering the latter more suitable for use when exposed to attacks of marine organisms, has occurred for the last fifty years." Here there is a large field for research, that the committee are determined to occupy.

The variable success attending the use of creosote can best be shown by a few examples. At Portsmouth, creosote applied under pressure has given satisfactory results. At Colombo, a jetty in which the timber was creosoted with 12 lb. to 14 lb. per cubic foot had to be replaced by a work in concrete. A temporary pier built of creosoted pine, at Bangor, County Down, suffered very severely in a few years. The piles, of section 12 in. by 12 in., were completely eaten through at the point where they entered the sand, about the level of low water. At Glasgow, on the other hand, timber impregnated with 8 lb. of creosote oil per cubic foot has been found to be effectually preserved, and piles driven about fifty-eight years ago are still in good condition. At Grimsby, creosote has been found to be of small protective value against limnoria. The experience of Southampton shows that a quay of creosoted pitch pine piles was rendered unsafe in twenty years, and that one or two piles which were uncreosoted had to be renewed after fifteen years. Apparently, this observation gives a direct measure of the value of creosote protection, but nothing is said of the manner of application. At Dublin, high temperature creosoting has been found to be the most effective process on account of the large quantity of creosote absorbed, and generally success varies inversely as the hardness of the wood. There is no need to increase the number of examples to show the diversity of results obtained from creosoting, but the conflicting evidence points to the need of further experiment. This is the conclusion of the committee, who propose to test samples of timber of different qualities and characteristics, impregnated with the ordinary creosote of commerce, and also with a creosote into which ingredients have been introduced, that in the opinion of chemical experts may improve its preservative qualities. Samples of timber prepared in this country, in the tropics, and in a colder climate will be used in connection with these experiments. The timbers which appear best adapted to resist the propagation and development of sea organisms are too dense and hard to permit of the penetration in any material degree, of poisonous substances. Effective injection of suitable matter might, however, render softer wood equally serviceable as the harder in resisting the attacks of teredo and limnoria. These tests and experiments will be carried out at Plymouth, where

normal conditions may be expected, at Colombo, where tropical conditions prevail and where teredo have proved to be unusually active, and in New Zealand, where intermediate conditions may be anticipated with regard to temperature and marine biology. Experiments at a cold port in Canada will also be considered.

Other preservatives than creosote have been used with more or less success, as external paint, and in extreme cases, encasing the wood in a metal sheathing. At Table Bay, the result of some experiments is to show that the timber best calculated to resist the attacks of teredo, with which the waters are infested, is a soft wood, coated with some preparation of tar or similar substance which will soak into the timber. When paint is applied to hard wood, it forms merely a thin film on the surface and fails to penetrate. This external covering is quickly rubbed off by the action of sand and floating weed, and the teredo effects an easy entrance. The Curbo-teredo process has been practised at some Colonial stations, but is of comparatively recent introduction. This process consists in coating the wood surface with crude petroleum, and then charring the wood with a blow-lamp to the depth of ¼ in. At Sydney, N.S.W., where experiments have been carried on for two years, a qualified approval is given of the method as one "that does not render the timber perfectly immune from the attacks of marine organisms, but charring prolongs the life of the wood very considerably." Testimony of a similar character is furnished from Perth (W.A.).

Metal sheathing can hardly be regarded as a timber preservative since it provides merely a mechanical obstruction to the attacks of the sea borers. In practice, the general method is to cover the timber with tarred felt, over which the metal sheathing is secured. The method is effective if the covering is complete, but great difficulty is experienced in properly covering the joints between the timbers in braced structures. At Fleetwood, Lancashire, a lighthouse was protected by lead sheathing, and this effectually prevented all damage from sea organisms, but in the tropics where a more active enemy has to be encountered, it is doubtful if lead would prove a suitable material. Muntz metal is preferred as more resistent, and at Brisbane, where a local dense wood, ironbark, is used, it is said that the piles protected in this way will last indefinitely, or at least up to forty and fifty years. Concrete covering is sometimes substituted for metal as the material for sheathing and apparently with good effect, but at Portsmouth, the plan is said to be "not quite a success." The covering may take the form of "scupper nailing," that is, flat headed iron nails driven into the timber, so nearly touching each other that the space between them may rust over and form practically a continuous rust coating. Here there seems to be a race between the agents of attack and defence.

The measure of durability of various kinds of timber is quite a different problem from that of prolonging the life of any one species by artificial means. Many members have recommended after experience a local timber, as possessing inherently protective and preservative properties, but the considered opinion of the committee is that "the claims have not always been borne out by the results achieved in the works." Observations on the behaviour of local timber under the varying conditions in which it has actually been used are obviously of high practical importance as guides to the engineer, who often must be called upon to decide whether it were more economical to utilise a comparatively unknown local timber, or incur the additional cost of importing wood reputed to be of a more durable character. The widespread organisation of the Institution of Civil Engineers is of great assistance in the collection of reliable information from trained experts, who have ample opportunities of observing the effect of many factors that should determine selection under given circumstances apart from mechanical stress, the wave action on timber in exposed situations, and in river estuaries, may differ greatly, salt and fresh water has each its peculiar effect, water impregnated with chemical sewage is a fruitful source of deterioration, while there are other causes, apparently quite lawless in their action. Of two piles nearly in contact one will be eaten away and the other left nearly untouched, and this irregularity of action will be exhibited whether the timber has been creosoted or not.

In the present state of our knowledge, notwithstanding the many reports that have been collected under varied climates and conditions of exposure, the committee decided that it is impracticable to tabulate the timbers in any reliable degree according to their durability. An exception is made in the case of greenheart, for which the committee entertain a partiality. This is placed first in the list on account of the resistance offered to the action of sea-organisms, due possibly to the presence of juices, or deterrents, which retard the growth and activities of the sea parasite. This wood is in favour both at home and abroad. Mr. Newell, Engineer-in-Chief of the Mersey Docks and Harbour Board, insists on the fitness of this wood for construction work in river estuaries in England, by demonstrating the condition of dock gates, erected in 1857, that after a life of sixty-one years were still in first-class order "and likely to remain so for many years to come." The only protection used was gas tar. At Singapore, greenheart fenders were in serviceable use after eight years, though a highly prized local wood (ballow) would not last more than five years. At Bombay, Demerara greenheart suffered considerable deterioration especially from pholas, but the penetration was not deep enough to reach the solid heart wood. Simple hardness does not confer immunity. Several correspondents state that oak disappears with annoying celerity. At Hartlepool, elm rapidly disappears, at Southampton both oak and elm suffer severely, and elm had only a life of seven to ten years at Portsmouth. It was found at Sydney that "ironbark," a very hard and close-grained local timber, perished as rapidly as pine.

Australian and Tasmanian timbers, of which the jarrah, karri, and blue gum are the best known examples, have been highly recommended, and in home waters they have given satisfaction. At Dover, Southampton, Fleetwood and Yarmouth, blue gum and jarrah have shown few signs of deterioration, and the evidence from Yarmouth is particularly valuable, for the teredo is comparatively active at that port, and the wood has stood for twenty-five years with but small loss. At Purfleet (Port of London) Mr. Kirkpatrick has had under observation a jetty, built entirely of karri. From half-tide level to low level, the timber is perfectly sound, upwards to high water the surface is softened and decayed to the depth of about ¼-in. Above the level the wood is perfectly good and the damage to the middle part, though not explained, is apparently not due to marine organisms. Some trade effluent whose action is obscure may contribute. From tropical countries the reports are less favourable. At Singapore, blue gum piles were eaten through in eighteen months. The same fate overtook jarrah piles at Colombo in two years, while eleven months were sufficient to accomplish the destruction of a karri pile 18 in. by 18 in. at Table Bay. The evidence shows that these woods will not endure an exposure for more than a few years in the warm waters of tropical seas. One of the most satisfactory is the wood of the "turpentine tree," *syncarpia laurifolia*, of New South Wales, which at some stations has had a life of from twelve to fifteen years. Many corresponding members have undertaken at the instance of the committee to make experiments on the little known woods in use at various ports, not only with regard to the length of life under varying conditions, but also with the view of determining the transverse strength, by breaking small beams between points of support. Possibly new woods will be brought on the market, and certainly much information must be gathered ultimately from the ably conducted researches, that will be inaugurated under the scheme, but unfortunately the war has delayed the prosecution of the plan.

The effects of the admixture of fresh water with salt, or of water impregnated with silt and sewage, in promoting decay, are not directly determinable. Sewage itself is probably deleterious as shown by the report on Leith Harbour, where it is said, a pitch pine pier did efficient duty from 1848–1893. At the latter date, sewage was diverted into the harbour, and deterioration became rapid. Of course the results may be simply coincident in time, but both fresh water and sewage have a very deterrent effect upon the activities of marine pests. Mr. Kirkpatrick informs the committee, that no teredo is found above Gravesend, a fact to be explained by the considerable proportion of fresh water in the Thames estuary. The greater evil, in our water at least, is the presence of limnoria and similar wood borers, and the sewage is a distinct aid in ridding our harbours of this plague. The evidence from Dublin in this connection is interesting. Sir John Purser Griffith records that where the water was diluted with sewage the timber remained uninjured, whilst in the lower harbour where the water was uncontaminated, destruction was very rapid, until the advent of the oil vessels, when the leakage of oil into the harbour put an end to the activities of the worm. In Belfast, in the older docks, where mud and sewage accumulate, the timber does not suffer from limnoria, but as the newer quays are built nearer to the sea, the life of the timber is so reduced, that concrete will probably have to be substituted. In the neighbourhood of Cork, the quantity of teredo and limnoria varies approximately with the distance from the shore. There is no need to multiply instances, the evidence has amply established the fact that impurities, as well as the movement of sand and shingle, reduces the numbers, and consequently the ravages of the marine borers.

Reference has already been made to the possibility of finding a substitute for timber more resistent to the attacks of the teredo. Concrete, and especially reinforced concrete, appears to offer the necessary properties of strength, rigidity, and permanence, though the elastic qualities of timber may be wanting. In employing an inorganic material there is likely to be greater uniformity in behaviour and certainty in endurance. Timber is more or less effected by the climate and soil in which the tree is grown, the rate of growth, the period and method of felling, its age, maturity and seasoning, with other causes of disturbance. In concrete, there are not so many variable factors, the character and size of the aggregate are the principal and these are very much under control, once the appropriate proportions are decided upon. As experience increases, the possibility of standardising the process grows more hopeful. At present, it may be said with some certainty that the observed defects are entirely due to the corrosion of the steel reinforcement, owing to the penetration of water through the concrete covering. Insufficient amount of concrete easily suggests itself as the cause of the penetration, but this simple explanation does not cover all the observed facts connected with the corrosion of the steel. In the majority of cases corrosion has been noticed to be first observable about the level of high water neap tides. At Southampton, Mr. Wentworth Shields distinctly states that the rust action takes place only above high water level: "below high water neap tides where the piles and bracing are kept constantly wetted, they are still quite unaffected, but above that level, the piles, bracing, and underside of decking have suffered considerably." At Wellington, New Zealand, as again in the Port of London, no serious deterioration was found below high water level. Mr. Cullen, of Brisbane, considers that the action of moist air on the concrete is as effective as that of water. Mr. Kirkpatrick offers an explanation that covers many of the observed facts. He suggests that during the drying of the wet metal, corrosion proceeds rapidly as it is in contact with the air, consequently where the concrete cover is thin and moisture finds its way to the steel in wet weather, one may expect that corrosion will ensue in the periods of fine weather as evaporation continues and cause the concrete to crack. "Below high water moisture will not have time to dry and between the wettings and the steel is protected from those conditions which lead to rapid corrosion."

The signs of deterioration have been well observed, and evidence shows that the first sympton is the appearance of small spots of rust on the face of the concrete. Corrosion next extends in the direction of the reinforcing rods, and cracks can be perceived.

Once a crack is started water gains access to the steel, and the effect of corrosion is to force the concrete away from the bars allowing the entrance of more and more water. No doubt the effects of traffic and the strains of wave action tend to accelerate the opening of the cracks. Mr. Kirkpatrick states that the bursting force of the corroding steel is as high as 4,700 lb. per square inch, and he has had under observation at Gravesend a jetty where many of the beams became cracked throughout the whole of their lengths, exposing the bars. In some cases the whole side of the beam became detached.

Evidently the depth of concrete covering is an important factor in securing permanence of structure. Mr. Cullen at Brisbane is prosecuting a series of experiments to determine the most effective thickness varying the quantity from ½ in. to 2 in. Meanwhile general opinion favours the view that the minimum thickness should not be less than 1½ in. for piles, beams and similar work, while for decking a slightly less thickness might be permitted. Naturally, the obvious benefits that follow from rendering concrete impervious to water has suggested the desirability of applying a coating of some waterproof material, as tar, or ironite, to the surface of the concrete. Gas tar has been tried, but not very successfully, "perhaps because it was applied too late," says one authority. In the case of an oil wharf constantly saturated with oil no signs of corrosion were apparent. More evidence on the value of waterproofing is needed as its use has not been general or long continued. No doubt regular repetition would be needed as Mr. Hamer, of Auckland, New Zealand, points out.

It is satisfactory to note that no defects in reinforced concrete are attributed to the concrete itself, and equally interesting that few remarks are made upon the composition and character of the aggregate. The inference to be drawn from this silence is, that such matters as the mixing, placing and ramming have become systematised, and that the controlling factors in producing reliable concrete are perfectly understood. The contrast with earlier experience is striking, and the committee direct attention to the misgiving, with which the engineering world thirty years ago viewed the employment of ordinary concrete in the construction of dock and harbour works. The defects which undermined confidence owed their origin to porosity in the concrete itself and the infiltration of sea water. Wherever sea water can soak into the concrete and subsequently exude, the magnesium salts in the sea water withdraw a portion of the lime of the cement in the form of calcium salts, and leave a deposit of magnesia in its place. An example of this action is reported from Scarborough and other places, but the damage generally is not serious. In very cold climates as at Halifax (N.S.) frost may be the cause of injury. In some concrete-in-mass piers, water penetrated the surface of the concrete at the time of high tide. When the tide goes down, the water in the concrete freezes and expands, and upon thawing again with the rising tide, the surface film of concrete falls off in powder. For such temperature effects, waterproofing is apparently the only remedy. Where high-class work is needed the committee recommend the use of concrete in the form of seasoned blocks, made above tide level, and stacked for two months before being set in position in the permanent work. Further for sea work, they are decidedly in favour of using Portland, rather than Roman, cement, and the use of lias or hydraulic lime in concrete is disapproved.

Allusion has already been made to the gradual displacement of cast-iron by wrought-iron and this again by steel. The action of sea water upon each of these is different, but the extent of the deterioration, its causes and its prevention, cannot yet be decided with certainty. As a rule it may be said that wrought-iron exhibits signs of decay quicker than cast, and steel quicker than either. Some engineers have expressed the conviction, that the finer the quality of the material the more rapid is the rate of corrosion and the greater the deterioration. In the outer Thames estuary of the Port of London cast-iron appears to be almost unaffected by the diluted sea water. Cast-iron piers exist in very good condition at Gravesend after having stood the wear of seventy-three years' tidal variations. At Holyhead, cast-iron columns erected fifty years since show no signs of severe deterioration, though both there and at Dublin the conversion of the surface of the metal into a soft ferrous oxide has been noticed. From New Zealand and Madras, equally good reports are forthcoming. Wrought-iron at Gravesend exhibits deterioration from electrolytic action at points of attachment to cast-iron. The condition gives rise to no anxiety though considerable erosion exists about high water level. The threads of screw couplings on ties fixed in 1894 are still clean and sharp, but from other places both at home and abroad the presence of deep pit holes and other signs of decay are reported. Marine growth and the attachment of shell fish seems to act as a preservation in some cases, but often, when this accidental accretion is removed unsuspected pits are found in the metal.

The references to steel structures of comparative recent erection and a general comparison between the behaviour of wrought-iron and steel when employed in structures in temperate, as compared with tropical, climates, though much to be desired, cannot be deduced with confidence from the reports. Madras, however, provides some very precise information showing that a beam originally weighing 1,628 lb. was reduced in weight to 663 lb., after eight years' use. Other beams, similarly situated, show a loss in weight, after the same period of time, from 20 per cent. to 59 per cent. At Karachi, an angle steel brace lost 22 per cent. by weight through corrosion in thirty years. Here, as in a majority of cases, the corrosion was worst at about half tide level. A curious instance is reported from Auckland (N.Z.) where some of the flat bar tension members just above water level, though kept carefully painted became pitted in circular patches. Though the metal was cleaned bright with a file, no paint or tars could arrest the rapid local corrosion on the bars, although adjacent members remained perfectly sound. This corrosion was attributed to some defect in the chemical composition of the steel.

In view of such peculiarities, and in the lack of exact information, the committee have, as we have already stated, arranged for experiments to be made on an extensive scale on different qualities of steel and iron of known composition. Samples have been procured for the rigorous testing of medium carbon steel, mild steel, Galahad non-corrosive steel, nickel steel, Swedish charcoal iron, and of two qualities of cast-iron. The object of the experiments will be to ascertain whether it is possible, by means of certain alloys, to produce a quality of steel, which will resist, more or less completely, the corrosive action of sea water, and whether the use of such steels in juxtaposition with ordinary or less costly steel, will be liable to give rise to electrolytic action. The bars of each description of the material, 80 in number, have been especially manufactured, complete chemical analysis have been made, mechanical tests applied, and arrangements perfected for their exposure in sea water, and in air, with the view of alternating the susceptibility to corrosion of each of the classes. Three complete sets will be exposed at selected stations, the first set to be taken up and examined after five years' exposure, the second after ten, and the third after twenty years' exposure. The periods may, of course, be curtailed if found desirable, after the first or second examination.

The research will also include a biological investigation, by competent authorities of the life history of the marine organisms by which so much damage is done to harbour works. Only by an investigation of this kind can really useful information be acquired as to the best means of effectually combatting the destructive work of these organisms. The field of inquiry is a wide one and may be expected to yield results of exceptional interest.

It will be evident from what we have stated that the committee are prepared to embark upon an enterprise of no ordinary magnitude; one worthy of the industrial importance of the subject and of their own reputation. It is fortunate that the Institution of Civil Engineers—a corporation possessed of such prestige and facilities, by reason of its widespread network, and the high professional standing of its members—should have engaged in this most important research. The united work of the Committee and of the large number of harbour engineers, in all parts of the world, who are associated with them, will deserve and command universal attention as the authoritative utterance of collective science and professional experience.

NOTES.

The Consistency of Portland Cement, Mortar and Concrete.

The correct proportioning of water to get a desired consistency in the mixing of Portland cement, mortar and concrete formed the subject of a paper read by Mr. H. G. Lloyd, M.Inst.C.E., before the Concrete Institute on Thursday, the 22nd inst. Mr. Lloyd has endeavoured to arrive at an exact method with the idea of superseding the trial and error system now generally used, in which the results depend so much upon the skill of the individual doing the mixing. The author of this paper, who has had considerable experience with concrete on the works of the London County Council, takes a sample of each ingredient, and proportions the water required to each of them in turn, instead of to the whole in bulk. The proportion of water needed for any cement is obtained readily by the "Boulogne" method, the exact amount being that required to give a ball of cement a consistency such that it will retain its shape when dropped from a height of 20 in. The result of this admixture of water with the cement may be said to give a "standard" consistency, which is a fairly clearly defined physical condition. In the case of mortars extra water must be given to wet the surface of the sand. The required proportion is obtained by weighing a dry sample, and then wetting it, and, when all superfluous moisture has been removed, weighing it again. The additional weight as a percentage gives the proportion of water to be added to damp the sand. Combining this with the Portland cement we get $W = \frac{Cc + Ss}{C + S}$ where W = the percentage of water by weight required by the combined weights of Portland cement and sand; C = the number of parts by weight of dry Portland cement; S = the number of parts by weight of dry sand; c and s respectively equal the percentage of water required by the Portland cement and sand. In the case of graded material or concrete, another term may be added to both the numerator and denominator of the fraction similar to those given, but relating to the aggregate and its required percentage of water by weight. The result, according to the author, may be termed mortar or concrete of standard consistency. It is now possible with this basis to start on, to specify the various consistencies to be adopted for different kinds of work, these mixtures having a plus or minus per cent. consistency, according to the water to be used. For instance, if 10 per cent. more water were desirable the mixture would be one of plus 10 per cent. consistency. If a drier mixture were needed it would be, say, of minus 5 per cent. consistency, the percentage being the proportion of the added or subtracted amount to the whole water required to produce standard consistency. In this way Portland cement for pointing may be specified as requiring a consistency of plus 16 per cent.; mortar for troughed bricks a plus 23 per cent., while for certain work a dry mixture or minus consistency may prove advisable. The method makes it possible to specify definitely how mixtures are to be made for various parts of works, and also eliminates the personal factor in comparative tests made with different materials by different persons. Evaporation may be allowed for, and also the varying absorbent qualities of different materials by the introduction of a simple factor in the formula.

The Cost of Aerial Transport.

Further data as to the cost of aerial transport schemes, which may be compared with those already given by Capt. Acland on page 520 *ante* and by Air Commodore Maitland on page 554 *ante*, were included in a paper read on Wednesday last before the Royal Aeronautical Society by Major General Sir Sefton Brancker, K.C.B. We shall confine our

attention to the figures given for a mail service running between Karachi and Constantinople, which, General Brancker considers, would be preferable to the Karachi-Cairo route recommended by Lord Weir's Committee. He proposes that mails carried by aeroplanes over the former route should go on to London by the Orient express, since this part of the whole journey from England to India is more liable to bad climatic conditions and to international complications. The distance to be covered by aeroplane is 2,700–2,800 miles, which could be divided into very convenient stages, the longest being about 380 miles. It is suggested that the enterprise should be started with a bi-weekly service, and allowing an average speed of 78 m.p.h. the distance could be covered in 35 hours, or three days flying only by day. This would involve 7,280 hours flying per annum, and, in the comparatively clear climate which exists on this route, Major Brancker considers that 20 machines would be ample to maintain the service. These machines would be capable of carrying 1,000 lb. of mails, or four passengers, at 80 m.p.h., and would cost £4,000 each. Allowing £7,000 for spare engines, £40,000 for spare parts, £20,000 for mechanical transport and communications, £20,000 for tools and miscellaneous items, and a working capital of £43,000 would bring the total capital expenditure required to £210,000. The annual overhead charges, which include shed and housing accommodation rented from the Government, pay of *personnel*, allowances, travelling, &c., are put at £60,000, while fuel would cost a further sum of £21,900 per annum. Depreciation at 50 per cent. comes to 40,000*l.* and insurance, at 20 per cent., to 16,000*l.*, so that the total annual expenditure amounts to 140,000*l.* With this expenditure 2,000 lb. of mails could be carried each way each week, and, if it were possible always to obtain a full load, the income at 1*s.* per ounce would amount to 166,400*l.* per annum. The working cost of 140,000*l.* for 7,280 hours flying per annum comes out at about 5*s.* per mile, and, if 6*s.* per mile could be earned, the profit would amount to about 29,000*l.* per annum, or nearly 14 per cent. on the capital expenditure of 210,000*l.* Passengers would thus have to pay 1*s.* 6*d.* per mile or 210*l.* each for the whole journey between Constantinople and Karachi, occupying three days. At this rate it certainly appears to us that Air-Commodore Maitland's scheme, according to which the whole journey between England and India could be accomplished by airship in 4½ days at a cost to each passenger about 100*l.*, is by far the more attractive proposition. To earn 6*s.* per mile flown 7½*d.* per lb. per 100 miles would have to be charged, or 13*s.* 5*d.* per ton mile, and this does not compare very favourably with the figure of 2*s.* 9½*d.* per ton mile put forward by Air-Commodore Maitland. General Brancker distinctly disclaims all desire to be unduly optimistic, and the figures he gives might possibly be considerably improved. As they stand, however, we fear that they rather tend to strengthen the view that airships provide the more suitable means of aerial transport for long journeys of the type considered.

RESEARCH IN AERONAUTICS.

It is doubtful whether even the most enthusiastic member of the Advisory Committee for Aeronautics could have foreseen, at the time the committee was appointed in 1909, the immense development in its work which would take place during the first ten years of its life. Prior to the war, it will be remembered, the committee's annual reports gave a brief summary of the research work carried out under the control of the committee for the year under review, and were accompanied by appendices in which the work was set out in detail. The data given in these reports were of great value to designers of aircraft, both at home and abroad, and the early reports still constitute a useful and interesting record of the development of the science of aeronautics. During the war it was, of course, essential to prevent the valuable information obtained from the work inaugurated by the committee from reaching the hands of the enemy, and, for this reason, no report has been issued to the public since that for the year 1912–13, although the results of all investigations were communicated to aircraft manufacturers, departmental officers, and other persons directly interested. There is no doubt that this policy did much to establish the superiority of British aircraft during the war, and that it contributed, in no small measure, to the satisfactory termination of the conflict. After the signing of the armistice it was decided that the material accumulated during the war period should be published as soon as possible, and many of the reports to the committee, which had to be treated as confidential while the war was in progress, can now be obtained for a few pence each from H.M. Stationery Office. In future, reports on current work will be published separately in this way as soon as possible after approval by the committee—a practice which is distinctly preferable to the pre-war custom of publishing them annually as appendices to the committee's report. The latter, which has just appeared for the year 1918–19, gives a brief *résumé* of the whole of the work done during the war period, with a supplement in which a rather more detailed statement of the work of the various sub-committees is given. There are now four sub-committees, dealing respectively with engines, light alloys, aerodynamics and meteorology, and another special committee for investigating the effects of atmospheric electricity on balloons, all of which make monthly reports to the Advisory Committee; the committee also receives regular reports from the Air Inventions Committee, and the Accidents Investigation Committee formed by the Air Ministry. As, however, the report and supplement together form an octavo pamphlet of only 77 pages, it will be obvious that they can do little more than indicate the lines on which the investigations have been made and the general conclusions reached; further information is, however, available in the reports obtainable from the Stationery Office, as mentioned above. Extensive as is the work already accomplished by the committee, so many problems are still awaiting solution that its labours can only be said to have made a good beginning, and, now that the nation seems to have awakened to the value of scientific research, there should be no difficulty in obtaining the funds necessary to continue the work on a scale commensurate with its importance. Any expenditure in this direction will be more than repaid by even a small percentage saving in the amount which will eventually be spent on aircraft for civil transport and for defence, and, quite apart from considerations of future economy, continuous research is essential if we are to maintain the leading position in aircraft design and construction reached during the war.

EBULLITION, EVAPORATION AND TENSILE STRENGTH OF LIQUIDS.

Some of the experiments made by Principal S. Skinner, M.A., of the South-Western Polytechnic, in the course of two lectures given in the last two weeks at the Royal Institution, once more emphasised how little we understand even common processes like the boiling of water. Mr. Skinner took a flask of boiling water from the burner, stoppered the flask, and poured cold water on it; the liquid recommenced to boil, not in small bubbles as before, but in big bubbles thrown up with almost explosive violence. The point, he explained, was that the heat now came from the water inside itself, not through the glass from the burner, and that the adhesion between the glass and water seemed in some way to be lowered. That adhesion he exemplified in several ways. When a U-tube containing some liquid and a partial vacuum was cautiously inverted, the liquid adhered to the closed end of the limb, and a very long barometer tube supported 42 in. of mercury although the air pressure would only balance 30 in., the additional 12 in. being supported by adhesion. When a glass beaker was smeared inside with oil or rubber, the boiling point of the water in the rubber-beaker was raised to 105 deg. C.; then a slight explosion took place, and the temperature dropped to 102·5 deg. C. That the water had not taken up any impurity from the rubber, was proved by pouring the water from the rubber-beaker into a clean glass beaker; the thermocouple in the rubber beaker again indicated the higher temperature. Mr. Skinner exhibited a boiler tube badly bulged and cracked —in consequence of oil adhering to the iron and so preventing contact of water—lent to him by the Paterson Engineering Company whose filter-plants for oily water he described. The phenomena of evaporation and of the dry and wet-bulb thermometer were not by any means sufficiently simple either, he remarked, to justify examiners in selecting the problem for the Oxford local examination—one of the not infrequent cases, we are afraid, where examiners set very hard problems lest their own competency be questioned. Maxwell had given a formidable formula for evaporation in still air. The original simpler formula of August and Apjohn for evaporation in moving air could not be correct, however, since it presumed uniform saturation. Experimenting with gas currents at various velocities Mr. Skinner had found that the formula $p_1 - p_0 = 0{\cdot}47\ (\theta_0 - \theta_1)$ held for water evaporation in air currents of 4 m. per second and more, the 0·47 being the value of the constant $= P\,S/L\,\sigma$, where p_1 was the pressure of the aqueous vapour at the wet bulb temperature θ_1, p_0 the air pressure at θ_0, P the atmospheric pressure, S the specific heat of air, L the latent heat and σ the density of water vapour referred to air. That formula affected many common phenomena. It was said, *e.g.*, that water could be boiled in a paper cup because the water cooled the paper, but the water would not quite boil in the paper (unless it were greased), because the cup was insulated by a vapour jacket; the same vapour jacket also explained cooking in paper bags and the Leidenforst phenomenon, which Mr. Skinner demonstrated by a modification of Poggendorff's experiment. A drop of water fell from a capillary into a platinum dish heated by a burner; the drop floated on its own vapour; a wire from the circuit of a tungsten lamp dipped into it, the platinum being joined to the other terminal. The lamp only showed a momentary faint glow; but when the burner was removed and the platinum cooled, the red glow became persistent and finally turned bright, as soon as contact between the water and platinum was established. In a similar way fire extinction by water jets appeared to be due rather to the intense evaporation of the many globules formed than to the mass effect of the cold water. In his demonstrations of the tensile strength and lubrication problems Mr. Skinner made use of solutions of fuchsin in glycerin placed between lenses or cylinders and flat plates, rocked by hand pressure or by a weighted pendulum. When the pressure was on the right, some bright, sometimes crescent-shaped, spots indicating the breaking of the liquid film were seen to the left of the point or line of nearest approach between the two surfaces.*

SURPLUS AIRCRAFT MATERIAL.—We recently had an opportunity of inspecting, at the Waddon Aerodrome, some of the surplus Government aircraft material which, as stated in a paragraph on page 414 *ante*, has been purchased for disposal by the Aircraft Disposal Company, Limited. Altogether about 10,000 aeroplanes, ranging from Handley Page night bombers of the V/1,500 type to Sopwith "Snipes," and some 30,000 aero-engines, of practically every make, size and type used in the war, are included in the equipment taken over by the company, as well as an immense quantity of instruments, accessories and spares. These are now stored in six depots similar to that at Waddon, and the contents of 130 stations in different parts of the country have still to be handed over to the company. The equipment will be disposed of mainly to foreign Governments and to commercial aviation concerns and other users of aircraft in all parts of the world, but much of it is quite suitable for use in other industries. There are, for instance, several hundred tons of ball bearings, about 350,000 sparking plugs, upwards of 100,000 magnetos, and innumerable bolts, nuts, and other small parts, all of which should help to relieve the existing shortage of manufactured goods. Some types of aeroplane engines, we understand, have been found to work quite satisfactorily on town gas, and, when run at a moderate speed, so as to reduce wear and tear, they are said to form compact, reliable and efficient power units for many purposes. It is suggested, for instance, that they may be employed in small electric power stations to assist the ordinary plant at times of abnormal load. The material has, of course, been purchased for considerably less than its original cost to the Government, but the company has arranged to return to the State one-half of the profits realised on its disposal. Messrs. Handley Page, Limited, of Cricklewood, London, N.W. 2, are the sole managing and selling agents for the company.

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* Compare the similar experiments of Toepler, ENGINEERING, November 1, 1918, page 495, and for the theory, see ENGINEERING, August 11, 1918, page 130.

INDUSTRIAL NOTES.

THE issue for April of *The Industrial League and Council Journal* gives an interesting summary of the advantages which the workers have gained from Whitley Councils up to the end of March. The summary covers 25 trades and industries, and for the first one reviewed by the journal, namely, Asbestos Manufacture, a minimum wage has been fixed of 9*d.* per hour for men and 4½*d.* for women, with an increase of ½*d.* per hour for each 10 per cent. by which the cost of living exceeds the 1914 standard; the wages to be reviewed quarterly. An agreement has also been arrived at according to which all employees having over six months' service are to have a week's holiday per annum; those with one year's service to receive full pay and those with less to have half-pay during the holiday time. In Bobbin and Shuttle-making, a wages agreement has been concluded by which all men over 21 receive an advance of 4*s.* 6*d.* per week; all women over 18 an advance of 3*s.* 6*d.* per week; and all juveniles an advance of 1*s.* 6*d.* per week. The journal announces for each monthly issue a similar summary. The issue for April contains other articles of interest to both employers and employed.

The forty-eighth annual report issued by the United Patternmakers' Association for the year December 31, 1919, states the following in the address to the members: ". . . We have turned down amalgamation with the bulk of our brothers in the engine shop; put before you in what was undoubtedly the best scheme yet produced, as evidenced by its acceptance by 10 unions out of the 15 which balloted, most of them showing strongly in favour, our own society was the only one, with three more numbering 1,537 members between them, who voted it down. A momentous decision, one which will need all our fortitude to substantiate as a wise and well-considered judgment . . ." The report shows a total of 115 branches, including the general office, and a total membership of 11,668. The balance in hand on December 31 last was 174,493*l.* in round figures.

A dispute has arisen in the gas industry all over the country. It is stated to involve 154 municipal corporations, 110 urban district councils, 961 private companies and 68 factories producing their own gas, and a total of about 100,000 workmen. Last week, the National Federation of General Workers issued the following statement:—

"The Joint Industrial Council for the gas industry have had before them for some time an application in respect to annual holidays and week-end and overtime rates, and the employers have given a final offer in settlement of this question which applies only to gas undertakings with an output of over 50,000,000 cub. ft. per annum. On the top of that the National Federation of General Workers, at the request of the affiliated unions concerned, sent to the Federation of Gas Employers a week ago an application for an all-round general increase of 10*s.* per week on the existing wages rates. A letter was received from the employers yesterday (April 20), stating that having regard to the financial position of the gas industry, the Federation of Gas Employers were unable to pay the increase demanded. This reply was discussed at the conference to-day (April 21) by the workers' representatives on the Industrial Council, and they passed the following resolution: That a copy of the original application respecting wages, annual holidays, and week-end and overtime rates, together with the employers' decisions with respect to each, be sent to the Executives of the affiliated unions concerned, with the recommendation that the unions agree to an immediate ballot of their members on the question of whether they are prepared to tender notices in support of our proposals. That the Executives of the unions be asked to give their decision within six days, and in the event of the unions' decision being favourable to the tender of notices, the National Federation of General Workers be requested to issue a uniform ballot paper to the affiliated unions at once, the result of the ballot to be notified to the National Federation of General Workers, and the pooled vote of the unions declared from the federation offices."

The Federation of Gas Employers state that they are not able to allow the 10*s.* increase referred to, by reason of the financial position of the gas industry. We understand that they made an offer of an annual holiday of one week and certain overtime rates, but at a meeting of the men it was decided that acceptance of this could not be recommended. The gas workers were granted an advance in January last of 5*s.* per week to men in undertakings making 100,000,000 cub. ft. of gas per year; 4*s.* to those in undertakings making down to 50,000,000 cub. ft. and 3*s.* to those in undertakings making the latter figure or less.

A Bill to provide that when a ballot of trade union members is taken on questions relating to strikes it shall be conducted by independent public officials and under a system of secrecy was introduced in Parliament last Friday, by Mr. A. M. Samuel.

The Bill proposes that such ballots shall be regulated and supervised by a Trade Union Ballot Regulation Committee, to be composed as follows: The President of the Board of Trade, or a representative nominated by him; the Minister of Labour, or a representative nominated by him; the Registrar of Friendly Societies; the chairman of the Parliamentary Labour Party; the chairman of the Trade Union Congress; the secretary of the Parliamentary Labour Party; one other person appointed by the Trade Union Congress. Penalties are provided for misuse of ballot papers or intimation. There voted for the second reading 83, against 77, majority 6.

On the monthly report for April of the United Society of Boiler Makers and Iron and Steel Shipbuilders, the general secretary, after referring to the award of the dockers' inquiry (16*s.* per day on the basis of the 44-hour week), writes: "I read the award and I congratulated the dockers on their clever leadership. At the same time, I felt depressed to think that whilst we, as an amalgamation, did our best to have our 44-hour claim sent to the same kind of court, we were outvoted by a majority of the leaders in the engineering and shipbuilding trades. More than this, it was partly our public advocacy of this form of inquiry that influenced the dockers in having their claim dealt with in this way. We have taken another way. The dockers' inquiry has taken less than two months. Our inquiry looks as if it will take two generations. We first made our claim for a 44-hour week in May, 1918. We have been negotiating ever since. We will go on negotiating until our members, who want a 44-hour week, take the job out of our hands. These negotiations of ours are only hindering the political efforts we are making to obtain the 44-hours by Act of Parliament. One-half of that committee is opposed to the 44-hour week. No inquiry will alter their opinions. Even if they found it would pay it would be too much liberty for working men. They would have time to think. When they do think, they will get as good an opinion of their own value as an independent court has of a casual labourer, and they will say: 'I should have a minimum of 16*s.* a day (4*l.* 16*s.* a week). I should have 16*s.* a day when I am sent home for want of work. The time has gone past for keeping me on the poverty line. Much loss would be avoided if I were managing the works with the others.'"

Following upon a resolution which was passed at the annual general meeting of the Associated Society of Locomotive Engineers and Firemen, held last year in Leeds, the National Executive have put before the newly created Central Wages Board a national demand for a wage of 1*l.* per day for drivers, 15*s.* for firemen. The present flat rate is 15*s.* for drivers and motormen and 11*s.* 6*d.* for firemen. It is stated that this new demand is to be considered by the Central Wages Board, and, failing agreement, by the National Wages Board, as a purely A.S.L.E. and F. application, quite apart from any claim of the National Union of Railwaymen.

A conference was held last Friday between the representatives of the dock employers and dock workers at the close of which the following official statement was made: "On the understanding that an agreement on the points, now under consideration, if arrived at, as is anticipated, the 16*s.* minimum daily wage will come into force for all men now on day rates, as from May 10 next, and permanent men covered by the report on weekly pay will receive a full week's pay, calculated on the new rates, as affected by this increase on the pay day next following May 10." It was further stated that the negotiations were proceeding in a good spirit, and that satisfactory progress was being made.

The ballot in the cotton trade referred to in our last issue has given the following results: Spinners, for a strike, 20,744; against, 1,623; majority for, 19,121. Cardroom workers, for a strike, 60,956; against, 3,341; neutral, 1,147; majority for, 57,615. Sir David Shackleton, one of the Permanent Secretaries, Ministry of Labour, is having interviews with both sides, with a view to bringing about further conferences to discuss the situation. The weavers' executive have decided to submit their claim to arbitration, provided that agreement is reached on the terms of settlement.

An increase of 2*s.* per week has been awarded to Admiralty dockyard employees by the Industrial Court. The application was made by the Federation of Engineering and Shipbuilding Trades and the Workers' Union, and the employees affected are riveters and caulkers, whose basis rate of 37*s.* per week has been raised to 39*s.* per week. A similar application with regard to drillers, wiremen, welders, machinists and hammermen was not established.

An article in *The Times* of the 24th inst., from that journal's special correspondent in Rome, gives interesting particulars concerning workmen's councils in Italy. The correspondent states: "For months past Turin industries, particularly the metallurgical factories, have been struggling with the question of workmen's councils. In the metallurgical industry 'internal commissions' already exist which deal with questions arising in the daily work of the factories. These are directed to smoothing over difficulties, but 'factory councils' which are in the programme of workmen's organisations and the consideration of which has been promised by the Government would involve the co-operation of the workmen in the actual running of the factories. Experience of the working of the internal commissions during the last months has been very unsatisfactory. In defiance of the regulations under which these commissions exist they have been invoked continually during working hours, and I was informed that for the past six months the Fiat Company's factories have not had 1 hour's work unbroken owing to continuous appeals to commissions to settle trivial matters. The present strike (in Turin) arose out of a perfectly unimportant difference, the extremists thinking that the proprietors, who had winked at these infringements of factory regulations, could be coerced into yielding on the far wider question of the introduction of factory councils. The metallurgical strike developed into a demand for recognition of these councils, which have already been unofficially nominated in Turin factories, and the committee of agitation has demanded that they should be instituted and recognised in all Turin industries. A general strike was called for, and the response, if not universal, was considerable. But the proprietors have taken a firm stand on the question of principle. They have declined to consider the recognition of factory councils and insist that internal commissions shall have no discussions during working hours. In face of this attitude the strike has practically broken down. Responsible leaders of labour organisations and the Socialist Party have indicated that in their view the ground was badly chosen for a big struggle, especially in view of the fact that the whole question of factory councils will certainly come up for consideration in Parliament within the next couple of months. It is announced that work will be resumed in Turin in a day or two, except in the case of the metallurgical industries, which will await the working out of a formula that can be accepted by both parties to the dispute. The struggle has been postponed, and the battle will be joined in Parliament, which is the proper field for the settlement of such an important problem."

FLIGHT TO INDIA AND BACK.—We learn that the Blackburn Aeroplane and Motor Company, Limited, of Leeds, intend to enter for the 10,000*l.* prize offered by *The Daily Express* newspaper for the first return journey by air between England and India carried out under commercial conditions. The competition is open to all types of aircraft, and is not restricted to machines or crews of British nationality. A considerable cargo must be carried throughout the journey and severe limits are imposed on the time taken for the flights, in either direction, and also on the time between the arrival in India, and the departure therefrom; the whole flight must be accomplished between May 1 and October 31. The machine entered by the Blackburn Company will be one of their standard Kangaroo aeroplanes with twin Rolls-Royce engines, and it will be piloted by Mr. Reginald W. Kenworthy. The expenses of the venture, apart from the aeroplane itself, are being borne by *The Yorkshire Evening News*, which has done much to encourage aviation in the past.

PERSONAL.—Messrs. Connolly's (Blackley), Limited, Insulated Wire and Cable Manufacturers, state that in order to deal with the requirements of their Yorkshire and Northern clients, they have opened offices and stores at Bradfield House, 27, Hunslet-road, Leeds, and that stocks will be kept there of all their manufactures.—The following gentlemen have been appointed to represent the Institution of Locomotive Engineers abroad: Mr. W. F. Cardew, Locomotive Department, Great Indian Peninsular Railway, Jhansi, India; Mr. F. Ryan, Central Railway of Argentina, Rosario, Argentine; Mr. T. Otway Ruthven, Nigerian Railways, Ebute Metta, Nigeria, West Africa; Mr. J. Hogg, South African Railways, East London, South Africa; Mr. C. E. Watson, Chinese Government Railways, Canton, China; Mr. W. Pickersgill, Locomotive Superintendent, Caledonian Railway, Glasgow, has accepted the presidency of the Institution for 1920–21, and Mr. C. J. Bowen-Cooke, C.M.E., London and North-Western Railway, Crewe, and Colonel Kitson Clark, Airedale Foundry, Leeds, will act as vice-presidents.—Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, state that whilst their Central Commercial Department is now located at No. 3, Woodstock-street, Oxford-street, W. 1, all correspondence in connection with locomotives, ship construction or civil engineering matters, should continue to be addressed to their Head London Office, No. 6, Great George-street, Westminster, S.W. 1.

THE COMMERCIAL FUTURE OF AIRSHIPS.

TO THE EDITOR OF ENGINEERING.

SIR,—In view of the publicity which has been given to, and the interest which has been aroused in, Air-Commodore Maitland's most able and instructive lecture on this subject at the Royal Society of Arts last week, may I be permitted to refer to the correspondence on "The Building of Airships," which has already been published in your columns. In particular I would revert to my letter of July 7 last, in which I contended that there was no indication of any possible commercial future for airships. It is deeply to be regretted that, even with the enthusiasm naturally engendered by his official position and with all the weight of his experience behind him, Commodore Maitland was not able to put forward any definite or convincing evidence—or even indication—of a commercial future for airships. His claim that the "big airship will be a commercial proposition" is based on pure conjecture.

So far as it is possible to differentiate, the whole question of commercial flight by lighter-than-air craft revolves mainly about two points, viz., reliability of service and cost. With regard to the former, it is stated that the German airship "Bodensee" recently carried out 60 flights between Friedrichshafen and Berlin, in 64 days. This is undoubtedly a remarkable performance and a magnificent tribute to the, as yet, admittedly unsurpassed technical ability of the Germans in the design and operation of this type of aircraft. Whether such a pitch of perfection and reliability will be reached by English manufacturers of explosion motors, remains to be seen. However, in any case no figures are given as to the cost of maintaining the "Bodensee" service. All we know is that such a service appears to be practically possible at certain times of the year. Whether it is commercial or not is entirely another question. Moreover, apart from any consideration of climate, it is difficult to see what possible or relevant comparison can be drawn between the conditions obtaining in the case of the relatively short overland flights of the "Bodensee" and those governing the ambitiously suggested England-Egypt-India service; or even, in a lesser degree, that between this country and Copenhagen.

Turning now to the estimate of the cost of operation put forward by Commodore Maitland, the first point that strikes one is, perhaps, the fact that no adequate provision has been made for contingencies such as the serious accidental damage to, or even total loss of, a ship. The loss of a single airship would affect his balance sheet very adversely. Accepting for the moment Commodore Maitland's somewhat sanguine estimate of the future cost of airships, the total loss of a ship during its first year of life would add the sum of 160,000*l.* to the cost of the service. This sum, on the yearly flying basis assumed would more than double the operating cost of the service per mile and would do away with all dividends.

A further point to be criticised is the suggestion that the Governments concerned should erect the necessary bases and lease them to a company for a yearly rental of only 6 per cent. of the cost of erection. Whilst such a rental would normally be ample to cover depreciation, maintenance and repair charges, it will not provide for interest on the capital expenditure involved. This point appears to have been entirely overlooked.

In conclusion, I have only to suggest that airships will never become a commercial proposition until some radical alteration is introduced into their design, embodying entirely different principles of flight rather than a mere modification of materials or methods of construction.

Yours faithfully,

CECIL LIGHTFOOT, A.M.I.C.E.

9H, Cornwall Mansions, Regent's Park, N.W.,
April 26, 1920.

"THE PERFORMANCE OF MECHANICAL STOKERS."

TO THE EDITOR OF ENGINEERING.

SIR,—As you have published several articles by Mr. Brownlie on the subject of boiler efficiency, I venture to ask for the hospitality of your columns for a few remarks on his recent paper read at the Institution of Mechanical Engineers, on "Mechanical Stokers for Lancashire Boilers."

While Mr. Brownlie by no means condemned these appliances in his paper, he no doubt fully anticipated the opposition of all stoker makers to the views which he put forward. All engineers in charge of steam-raising plants have had the merits of stokers brought before them for many years, but it must have required considerable courage to present a paper for discussion which, to say the least of it, somewhat discounted their reputed advantages.

The figures given in the paper relate chiefly to installations of comparatively few Lancashire boilers in each battery and having many similar installations under my charge, and having both scrapped and installed several types of stokers, I am of opinion that the figures on the whole correctly represent current practice, and, further, that Mr. Brownlie is right in stating that on the average, the working efficiency of Lancashire boilers, fitted with mechanical stokers, is not higher than those being hand-fired. Both are deplorably low, and it is most important that the best results which can be secured by the installation of mechanical stokers should be compared not with what is done, but what can be done under careful supervision. With a view of making this comparison, some years ago I fitted up a Lancashire boiler with downtake superheater and economiser specially for investigating the improvements which could be obtained by the installation of various appliances, including mechanical stokers, brought forward from time to time.

Before any trials of additional apparatus were made, however, care was taken to get the boiler running regularly at a fair load and efficiency, which was found to be 72½ per cent. with good fuel and when employing a good average stoker. All the various forms of apparatus which were tried were put up against this as representing what was thought to be good commercial practice.

Having reached this point comparative tests were made after the addition of various appliances, and the opinion was definitely formed at that time that under equally good supervision a Lancashire boiler with downtake superheater and economiser would do very nearly as well without any additional appliances of any sort except in so far as they might enable one to burn very much cheaper classes of fuel. The conclusion was reached that mechanical stokers on Lancashire boilers could generally only be justified in very large installations or for the purpose of improving conditions of labour.

During the discussion of Mr. Brownlie's paper, it was suggested by one or two speakers that in any case the early advent of the super-power station would result in the disappearance of such small steam-raising plants as were under consideration, but this seems extremely doubtful.

Any really good modern steam engine of from 250 h.p. to 1,000 h.p. will produce a brake horse-power hour for 2½ lb. of coal containing 11,500 British thermal units to the pound when running long hours on a regular load, and for such conditions it is very doubtful whether the substitution of electric power stations, distribution systems and motors would be an attractive commercial proposition. It seems, therefore, that the efficiency of our small power plants with Lancashire boilers will probably remain an important matter for some years, both from the national and the commercial point of view, and the thanks of the profession are due to Mr. Brownlie for the information he has published on this subject from time to time.

Yours faithfully,

C. PERCY TAYLOR.

Milton Lodge, Gravesend, Kent, April 21, 1920.

A NURSERY OF ENGINEERS.

TO THE EDITOR OF ENGINEERING.

SIR,—It is fifty-four years since the leading engineers of Manchester and district met at the Town Hall and came to the conclusion that it was expedient "to establish a professorship of Civil and Mechanical Engineering at the Owens College." They appointed four men—Joseph Whitworth, Charles Beyer, William Fairbairn and John Robinson—to collect the necessary endowment, and the result was the appointment of Osborne Reynolds as Professor of Civil and Mechanical Engineering at Owens College, at the head of what became the first engineering laboratory in the country to provide a systematic course for the training of students in experimental engineering work.

It was indeed fortunate for the Owens College that from the first it attracted the interest and practical support of some of the most famous engineers of the day. They not only provided the funds required for the several extensions of the engineering laboratories, but by their contributions to the general funds provided the greater part of the assistance received from the public in the first twenty years of the history of the college—the bequests of Whitworth, Beyer, Clifton and Asa Lees, alone amounting to over 200,000*l.*

The selection of Osborne Reynolds as the first professor not only showed the breadth of outlook of these pioneers of engineering education; it was destined also from the first to place Manchester in the forefront of our universities. It can, I think, fairly be claimed that within the limits of our present equipment we have worthily carried out that great tradition. We have done valuable work recently on the failure of materials under combined stress, the flow of steam through pipes, the collapse of boiler flues, the strength of struts, and so on. Tests on full-size girders and braced structures have been carried out for local firms, and, in the years immediately before the war, extensive research was conducted for the Home Office Committee on Humidity and Ventilation in Cotton Weaving Sheds, with the object of determining which insulating materials or compositions were most suitable for covering steam pipes in these works, so that the unnecessary radiation of heat and consequent raising of temperature might be prevented. Thirty materials, involving some hundreds of observations, were tested, and this led to legislation regulating the standard of conductivity, whereupon the department, at the request of the Home Office, carried out the tests and issued official certificates. The official report declared that here the university's work was of the greatest practical value, remarking that the experiments were "probably more exhaustive and convincing than any that have yet appeared in regard to the lagging of steam pipes."

Here we have a solid benefit won for the Lancashire operative; nor must it be forgotten that our department may open up the way for the sons of the operative to posts of first-rate importance. Our students come not only from public schools and secondary schools; they include a fair proportion who are holders of scholarships given by different public authorities. For over half a century a stream of highly-trained men such as they have been going out every year to positions of responsibility in the engineering profession all over the world. Numbers have entered public departments such as the Indian Public Works, Ordnance Factories, Dockyards, Patent Office, Post Office, and so on. Many fill leading positions in large engineering undertakings; others hold appointments on the railways, while a few have entered the teaching profession, and 13 past students have filled university chairs.

But, if the Manchester School of Engineering is to retain its pre-eminence, considerable additional endowments will be required. The specialisations that have taken place in recent years make it impossible for any one professor to keep in touch with the latest developments of the numerous branches of engineering practice. The appointment some six years ago of Mr. Sandeman, lately chief engineer of the Derwent Water Scheme, to give part-time courses in waterworks engineering ought, in my opinion, to be extended. Similar special courses from four or five engineers of eminence in different branches of the subject, a substantial increase in the regular teaching staff of the department, and a large increase of laboratory accommodation and equipment, represent in outline the minimum requirements necessary to place the department in a position worthy of its past.

I would strongly advocate the appointment, as associate professors, of practising and consulting engineers each eminent in his own branch, to give part of his time only to university work. In no other way is it possible for the student to be given first-hand knowledge of recent innovations in engineering practice. The subjects covered should include: Railway engineering; internal combustion engines; aeroplane construction; structural engineering; municipal engineering; chemical engineering; canals, docks and harbours.

The commercial advantage to engineers in the Manchester district of such a strengthening of the engineering department consists first in the provision each year of a number of scientifically-trained men, who would be available for technical appointments. The thorough scientific training received at the university makes it relatively easy for such men to become familiar with the technical details of any type of engineering construction, and, given the opportunity, would prove their value by the introduction of new ideas suggested by the scientific study of the problem. The value of the scientific engineer has been proved over and over again during the war, and it would be strange indeed to suppose it ceased with the advent of peace.

In this respect, however, the immediate advantage to commercial engineers depends on the degree of co-operation they are prepared to make, not only as regards the work of the department itself, but also in providing facilities for the students to receive the practical training necessary for the equipment of the engineer. The summer vacations provide an excellent opportunity for students to spend about three months in works, and it is hoped that arrangements may be made whereby students wishing to avail themselves of such practical training will be given the opportunity.

A further advantage of a strengthening of the Engineering Department lies in the facilities for carrying out special tests of a commercial or scientific nature, for engineering firms in the district. A large number of such tests are carried out annually, but considerable additions to the testing appliances in the laboratory have become necessary in view of the advances made within recent years in the methods of testing. The laboratory cannot be considered completely equipped unless it possesses at least one machine for each standard type of test, and such machines would always be available for tests for private engineering firms at a nominal charge to cover working expenses.

There is, in short, no class of the community who would not reap the benefit of a strengthening of our department on the lines which I have suggested. It would be an evident gain not only to the science of engineering, and to those who study it, but to commercial engineers and the community at large.

Yours faithfully,

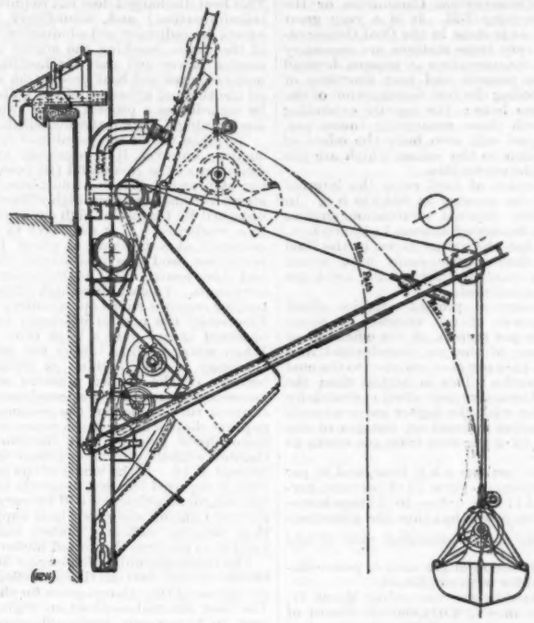
C. B. DEWHURST, M.Sc.,
(Clifton Lecturer in England).

Manchester University, April 22, 1920.

THE LATE MR. ROBERT MOODIE.—We regret to have to announce the recent death at Rayleigh, Essex, of Mr. Robert Moodie. Mr. Moodie was the designer of a separator having revolving plates, in which the finer particles of the material dealt with were separated by continuous air currents. This machine met with great success. His latest work was in connection with engineering plant having reference to developments in sulphuric acid manufacture introduced in the chemical works of Messrs. Spencer, Chapman and Messel, Silvertown, of which firm he was consulting engineer. Mr. Moodie belonged to a family which had been for several generations engaged in engineering and millwright work in the South of Scotland. He was 74 years of age at the time of his death.

CARBON BLACK.—The bulk of the 30,000,000 lb. of carbon black wanted per year by the ink, polish, pigment and rubber industries of the United States, is now made by burning natural gas in air. The carbon so obtained is a velvety black pigment very different from the greyish lampblack produced by burning oil or other carbonaceous material. Only a small percentage of the total carbon in the gas, from 1·5 per cent. to 3·5 per cent., is recovered as black, equivalent to from 0·5 lb. to 1·5 lb. per 1,000 cub. ft. of natural gas; yet the superior properties of the product justify the use of gas for the purpose. On the other hand the threatening exhaustion of the natural gas supplies has induced the United States Bureau of Mines to study new ways of producing the black from gaseous or liquid hydrocarbons by thermal or explosive methods without combustion in air, after mixing the gas with CO, CO_2 or O_2, but so far with little success. This investigation has been carried out by G. St. Perrott and R. Thiessen (*Journal of Industrial and Engineering Chemistry*, April, 1920). At present the gas is burnt in air, from lava-tipped burners, set at distances of 3 in. or 4 in. underneath steel channels which are given a reciprocating motion, so that the black deposit is scraped off; the steel channels are grouped in tables, sometimes 100 ft. long. The paper we quote from describes chiefly the properties and the testing of the black carbon.

STEAMSHIP COALING APPLIANCE.

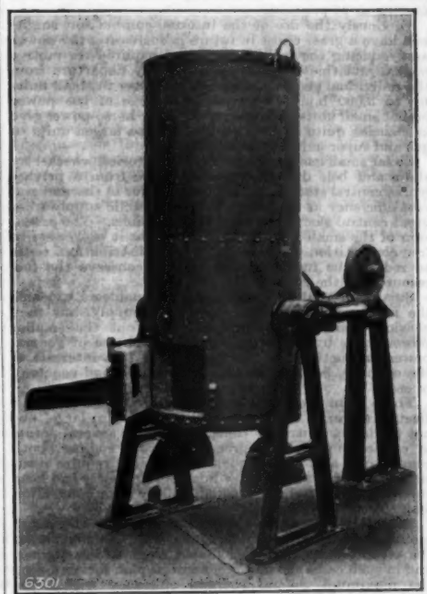


WE reproduce from our contemporary, *Marine Engineering*, the accompanying illustration of an interesting coaling appliance brought out by the Bergen Point Ironworks, Bayonne, N.J., U.S.A., several of which have been supplied to the United States Navy Department. The machine consists of a light A-shaped framework of structural steel, carrying a hopper and chute, with winding and luffing gear for the jib. The latter consists of an A frame pivoted at the base on the main frame. From the jib an ordinary grab bucket is suspended. The main frame is provided at the back with heavy hooks by which the whole machine can be suspended from the bulwarks, or side plating of the vessel. The bucket has a capacity of about 7 cwts. The luffing of the jib is automatic, the luffing rope being wound on a conical differential drum. The operator only has to attend to raising and lowering the grab. The maximum reach of the hook is 14 ft. from the side of the ship and the minimum 9 ft. 9 in.; by utilising the swing of the bucket it is stated that a barge of 32 ft. beam can be satisfactorily cleared. The hoisting and luffing motors are each 15 h.p. An electrical plug connection enables power to be taken from the usual ship supply. The appliance weighs about 4½ tons and has a capacity of about 50 tons per hour. The chute is telescopic and can be lowered through the side ports. The machine is also capable of being stood on the deck, and used with barrows, &c., it can be employed for loading through deck hatches. A seat is provided for the single operator who controls the working by means of conveniently placed levers.

CHEMISTRY OF THE NILE SUDD.—The sudd, masses of floating and fixed plants which abound in some of the reaches of the White Nile and its tributaries, seem well characterised by their Arabic name, which is said to signify blockage or dam. From the mouth of the Zeraf, 525 miles above Khartoum, up to Shambe, a distance of about 300 miles, a passage through the main river channel is at times kept clear only with difficulty, whilst the tributaries are blocked for many miles. Estimating the sudd area at about 5,000 sq. miles, A. Joseph, D.Sc., and F. J. Martin, M.A., of the Wellcome Tropical Research Laboratory, Khartoum (Journal of the Society of Chemical Industry, April 15), consider that the total amount of dried sudd, at the rate of 45 tons per acre, would be equivalent to 28,000,000 tons of coal. The chief plants in the sudd are a papyrus, a convolvulus, and a peculiar hairy grass, *paniculum pyramidale*, known as "Um Soof, mother of wool." Both the papyrus and the grass might become of importance in the manufacture of paper pulp and of potash; the ashes of the two plants contain 30 per cent. and more of potash, bound with other bases by silica. When the papyrus stems are digested with hot water at a pressure of 4 atmospheres, practically all the mineral matter and most of the proteins pass into solution, while the residue, forms a satisfactory "half-stuff" for paper. The bulk density of the uncompressed papyrus is only 0·1, however, and until the engineer discovers means of collecting and drying the sudd there is little hope of any utilisation, except on a small, local scale.

A PORTABLE CUPOLA.

THE Constructional Engineering Company, of Titan Works, Charles Henry-street, Birmingham, are manufacturing a series of self-contained cupolas for emergency work, one of which is illustrated in the figure below. These cupolas are equally useful for melting special mixtures or temporarily increasing foundry capacity, and a considerable number were used during the war in the motor repair shops on the Western front. The size illustrated is the largest of its type, having a



capacity of 7 cwt. per charge or 25 cwt. per hour. The overall dimensions of the whole plant are: 8 ft. in height; 6 ft. 6 in. in length from front to back and 4 ft. in width. It is claimed that 7 cwt. of metal can be brought down within 15 minutes of turning on the blast, and the melting results are said to average 3 cwt. of coke per ton of iron melted. Cupolas of this size are in daily use for melting metal to cast joints of tram rails in position. For this purpose they are mounted on the under frame of a tram car and run along the track to any place where it is desired to use them.

The "cupolettes," as they are called by the makers, are fitted with drop bottoms, tuyeres, sight doors, fettling doors and tapping and slagging spouts. They are supplied complete with fans and lining ready for immediate service. The two sizes smaller than the one illustrated have melting capacities respectively of 3 cwt. and 5 cwt. per charge, or 10 cwt. and 17 cwt. per hour. To facilitate re-lining all sizes can be swung into a horizontal position, and stays are provided for supporting them thus.

COAL CONSERVATION IN THE UNITED KINGDOM.*

By Sir DUGALD CLERK, K.B.E., D.Sc., F.R.S., M.Inst.C.E.

(*Concluded from page 545.*)

Methods of Saving Fuel Immediately Applicable.—In considering a general scheme of fuel-saving for the United Kingdom, it is necessary to take a broader view than has been done by the Government Committees. Not only should the efficiency for motive power be considered, but the whole heating systems of the country should be dealt with in order to obtain a combined efficiency of heating, lighting and motive power; to obtain a broad general view it is thus necessary to study not only the distribution of heat, light and power by gas and electricity, but also the other methods of generating and distributing heat for domestic and manufacturing purposes.

The gas industry has existed for over 100 years, and it is at present a highly economical user of the country's store of heat. I have already shown that in fuel economy it far surpasses the electrical industry on the average consumption of coal required for a general service of heat, light and motive power.†

In 1917 the gas industry carbonised 20,000,000 tons of coal, and the heat of 10·8 million tons was used to produce and distribute the coal gas utilised in the United Kingdom, while the heat of 9·2 million tons remained available for use in the form of solid coke and semi-liquid tar and oil. The coal gas was produced and distributed at 43·6 per cent. thermal efficiency, and its efficiency of use at the consumer's apparatus was 42 per cent.

Great changes are now in operation throughout the gas industry due to the adoption of the thermal unit standard for sale and the passing away of the intrinsic illumination standards so long adopted. These changes allow of greatly improved thermal efficiencies of production and distribution. In a few years the majority of gas works will deliver to the consumer in the form of gas 75 per cent. of the whole heat of the coal used and the improvement in gas apparatus, construction and design are so great that the efficiency of use of the gas will rise from 42 per cent. to 55 per cent.

The effect of these two changes will cause the consumption of coal to be reduced from 10·8 million tons per annum to 4·8 million tons, giving the same service of heat, light and power, as at present. If, however, the use of gas expands at its present rate a double service could be given on 9·6 million tons. If we retain the same service we save 6,000,000 tons per annum on the gas industry alone. The consumption of coal for domestic purposes was 35,000,000 tons in the year 1913 (see page 543 *ante*, Table I), and it is highly improbable that the average efficiency of use exceeds 20 per cent., including water heating and boiling, heating rooms by circulating hot water, cooking and heating rooms by open fires. The efficiency of the open fire is certainly much less than 20 per cent., although special tests with particular fires have given that result. My view as to average efficiency of open coal fires in the United Kingdom is about 8 per cent., but Professor Bone differs from me and suggests much higher values. It seems to me probable that Professor Bone will accept 20 per cent. as a high value for the average efficiency of the use of coal for domestic purposes.

I have shown that gas will shortly be produced and distributed at 75 per cent. and used at 55 per cent. thermal efficiency for general domestic purposes. That is, the ultimate efficiency from coal consumed at the gas works to heat utilised by the consumer is $0·75 \times 0·55 = 0·41$. From this it is evident that at the new higher efficiencies of gas it will economise the country's fuel resources to introduce gas to all households instead of coal for all purposes where coal is at present burned. This involves a very large increase of gas consumption and sale. On the assumption of complete displacement of coal in households by gas the saving would be one-half. Instead of using 35,000,000 tons we should only use 17·5 million tons. We save 17·5 million tons on this item. Further savings will be made by the rapidly increasing use of gas for industrial purposes, including many varieties of furnace work so well described by Mr. Thornton and other able gas appliance engineers.

Mr. David Brownlie, B.Sc., F.C.S., estimates that 15,000,000 tons to 30,000,000 tons of coal are used annually in boiler furnaces to raise steam for purposes of manufacture other than producing motive power. Assume that 20,000,000 tons are so used. Mr. Brownlie's examination of the tests on 250 typical boiler plants, including several boilers to each separate item, shows an average of 60 per cent. efficiency of evaporation and economiser; the evaporation being 5·56 lb. of water per pound of coal. Mr. Brownlie has proved that a steam boiler plant run on modern lines under skilled control

* The "James Forrest" Lecture, 1920, read before the Institution of Civil Engineers, April 20, 1920.

† "Distribution of Heat, Light and Motive Power by Gas and Electricity (Royal Society of Arts, March 19, 1919), and Report on the Coal, Gas and Electrical Supply Industries of the United Kingdom." By Clerk, Smithells and Cobb, April 14, 1919.

will give from 75 per cent. to 82 per cent. efficiency with ordinary steam coals or coke when care is taken to keep the plant in good condition.

If boiler attendants be better trained, and masters take some pride in obtaining best efficiencies, then 60 per cent. of average practice could be raised to 75 per cent. The 20 millions of tons at present used could be reduced to 16,000,000 tons, giving a saving of 4,000,000 tons per annum on this item.

The collieries of the country consume about 17,000,000 tons per annum on boiler furnaces for motive power at an average efficiency of 55·5 per cent. If this be raised to 75 per cent. then the coal bill becomes $\frac{17 \times 55{\cdot}5}{75} =$ 12·6 million tons.

The saving here would be 4·4 million tons annually.

Under this heading I again return to the question of improvement in motive-power economy. I am in complete agreement with the desire of electricians to produce motive power and light in a more economical manner than they do at present. I welcome the progress of electricity as shown from the coal controller's returns. Electricity is doing good work in the conservation of coal. The average consumption per brake horse-power for the whole country I estimate at 4 lb. of coal, but the electrical generation of the country has reached the lower figure of 2·6 lb. per brake horse-power hour. It has become as economical of fuel as the textile industries. The purpose of reducing it still further to 1·5 lb. and even 1 lb. is good and commendable, but the Coal Conservation Committee Report advocates a line of advance which follows the direction of "colossal" standardisation so characteristic of German ideas and development which ultimately brought that country to ruin when pitted against the organised individualism of the British Empire.

The report regrets the impossibility of sweeping away nearly all existing electricity generating stations and all private power producing installations and replacing them entirely by super-power stations on the assumption that economy can only be found in that way. The report assumes and states that "Large generating machines, not less than 20,000 h.p., must be used, and they must be erected in the best possible position for economical production." Units of 50,000 h.p. are then stated to be more advantageous.

This notion of the great gain to be expected from very large steam turbines is quite erroneous. The results to be obtained depend but little on the use of very high powers as will be seen from the following particulars showing the effect upon economy of increasing turbine dimensions. This table has been prepared by the most experienced turbine designers.

Approximate Steam Consumption of Modern Turbines, Alternators and Condensing Plants.

Steam Conditions.—Stop-valve pressure, 450 lbs. per square inch; stop-valve temperature, 750 deg. F. (300 deg. F. superheat); vacuum, 29 in. (barometer, 30 in.).

Electrical Conditions.—Three-phase, 50 periods; 0·9 power factor, say, 11,000 volts.

Cooling water, 60 deg. F.

Kilowatts.	Type.	Revolutions per Minute.	Full Load Consumption per Kilowatt-Hour.
10,000	Tandem	3,000	9·0
40,000	,,	1,500	8·68
50,000	,,	1,000	8·84
70,000	,,	1,000	8·6
100,000	,,	1,000	8·5

From this it is evident that even with the most modern plant which can be built an increase in power from 10,000 kw. to 100,000 kw. only reduces the steam consumption per kilowatt hour from 9 lbs. to 8·5. This table shows clearly the fallacy of the idea that very large stations are required to produce high economies. The results shown by the table are fully borne out by the analyses submitted by Mr. D. Wilson, of the Coal Controller's Department, at the discussion of National Electricity Supply at the Junior Institution of Engineers on January 27, 1919. Mr. Wilson's statements have been summarised in the table below.

Summary of Mr. D. Wilson's Statement at the Discussion on "National Electricity Supply" at the Junior Institution of Engineers, January 27, 1919.

Number of Stations.	Output.	Coal per Unit.	Thermal Efficiency.
	Millions of Units.	lb.	
421	4,674	3·47	8·49
381	2,399	·32	6·8
40	2,277	1·57	11·5
7	1,299	2·45	12·12
1	over 200	2·53	10·88
1	46	2·4	12·35
1	over 40	2·32	13·05
1	28	2·4	12·15
1	under 22	2·49	11·95
1	over 0·2	2·78	10·83

Of the whole 421 stations examined by Mr. Wilson the most economical station is one with an annual output of 40,000,000 Board of Trade units. The efficiency is 13·05 per cent. A much smaller station, giving an output of under 22,000,000 units, has a thermal efficiency of 11·95 per cent., and a very small station with an output of 0·2 of a million units gives a thermal efficiency of 10·83 per cent.; that is, in the actual examples dealt with by Mr. Wilson, the rise and size of station from 0·2 to over 40,000,000 units per annum per cent. to 13 per cent. Efficiency of station, then, does not depend upon dimensions in any degree corresponding to the expectations of Coal Conservation Committee or the supporters of the Electricity Bill. It is a very great error, then, to assume, as is done in the Coal Conservation Report, that the very large stations are necessary for improving the fuel consumptions at present devoted to motive power. The present and past exertions of engineers is rapidly reducing the fuel consumption of the country per brake horse hour; the rapidly extending use of gas engines, both those consuming towns gas, producer gas and oil fuel will soon have the effect of reducing fuel consumption to the values which are the aim of the members of the committee.

The census of production of 1907 rates the internal combustion engines of the country as 644,836 h.p. In the year 1919, stationary internal combustion engines of the United Kingdom developed at least 1,000,000 h.p., and it is to be noted that the values given in the Coal Conservation Report deal in the main with steam motive power; a very small fraction of the total gas power of the kingdom is included.

The towns gas industry at present supplies about 448,000 brake horse-power of gas engines, or about 1,344,000,000 h.p. hours per annum, at the efficiency of 25 per cent. of the heat of the gas transformed into brake horse-power, and 10·9 per cent. referred to the coal consumed at the gas-works. This is higher than the present efficiency of electricity generation: electricity gives 6·8 per cent. But with the higher gas-producing and distribution efficiencies referred to, the gas of the near future would give 18·5 per cent from gas-works to users brake horse-power.

Electricity at 1·56 lbs. coal per e.h.p. hour, and 90 per cent. efficiency of distribution, gives 11·9 per cent. current into the motor, and $11{\cdot}9 \times 0{\cdot}9 = 10{\cdot}7$ brake horse-power from motor. Gas power has thus the advantage of $\frac{18{\cdot}5}{10{\cdot}7} = 1{\cdot}73$. At the more economical rate of fuel consumption, a great extension of gas motive power distribution may be looked for with confidence.

The electricity generated in the year ending March 31, 1918, was, as has been shown, 4,674,000,000 Board of Trade units, which is equal to 6,260,000,000 e.h.p. hours. At the same rating, 3,000 hours per annum at full load, 2·08 million h.p. were produced electrically.

Gas power by suction and other producers mainly account for over half a million brake horse-power in internal-combustion engines, and here the ultimate thermal efficiency exceeds 20 per cent. This is the highest figure to which the electricians at present aspire.

A recent examination by me of the limits of thermal efficiency of gas and oil engines, shows conclusively that 45 per cent. brake horse-power may be obtained in the near future. Sir Charles Parsons at the same time prepared an estimate of the limiting efficiency of the steam turbine as 28 per cent.

Obviously the use of the internal-combustion engine will have a great effect in future in increasing the power and reducing the fuel consumption required for motive power, and this without requiring any departure from the individual generation of motive power in small units up to 3,000 h.p. The great advantage of gas power is that small units such as even 50 brake horse-power give efficiencies quite as high as that of the larger units of gas and super units of electricity.

So far small gas power driving for factories, whether by shaft and belt drive, or electric drive from a private works central station, have been superior in thermal and cost efficiency as compared with any public supply from great central electricity generating stations. The extension of the small power units, so long as it progresses in free competition with best electricity distribution, tends to reduce the fuel consumption and conserve the fuel resources of the country.

Steam, internal-combustion and gas engineers, welcome the free competition with electricity supply, but they consider that any attempt to crush out the smaller power units by a great government scheme of general power production will act against the best interests of the country, both as to coal conservation and economy in cost.

There is an enormous field ready for steam, gas, and electric power in separate units as well as in large, but not too large, central stations. There are several points in connection with reciprocating steam engines, both condensing and non-condensing, which require consideration, and tend to show how motive power and heat supply are at present connected, and by their connection lead to economy of fuel.

In factories large quantities of steam are used for many manufacturing and chemical operations. In some cases the steam so used is the exhaust from steam engines, and in such cases the more economical plan for obtaining the maximum general thermal efficiency within the works consists in discharging the exhaust steam from the engine at a pressure slightly above atmosphere, so that its temperature for the purpose of heat supply or chemical action is above 212 deg. F. A steam engine working under such conditions does not, of course, give the maximum thermo-dynamic transformation which is possible; but notwithstanding this, it may be advantageous from the total fuel consumption point of view of particular factories deliberately to make the steam engine uneconomical in thermal efficiency in order to leave the heat rejected at a level which renders it available for all the purposes of heating. Although the engine does not show the maximum thermal efficiency, the combination of engine and heat producing by steam gives extremely high thermal efficiencies. If all radiation and condensation losses could be avoided such a combination would give 100 per cent. thermal efficiency so far as the steam passing through the engine was concerned. When the steam is thus supplied to an engine, the expansion takes place in the cylinder, a certain temperature drop occurs due to work done on the piston, and the remaining heat in the steam discharged is available for the purposes of heating. This heat discharged does not require any thermodynamic transformation; and, accordingly, in this combination, except for radiation and conduction losses, the whole heat of the steam reaching the engine is available, part for motive power and part for heating. The efficiency of motive power and heat production will thus depend only on the thermal efficiency of the boiler. The system may be regarded as a process giving two products, each product having a certain thermal efficiency.

To make use of this combined system in using steam engines, however, it is necessary to dispense with condensation of the steam and the power obtained by working at pressures below atmosphere. In the case of the steam turbine, the very high efficiency of 19 per cent. is obtained by the use of high expansions and low pressure in a condenser. It is necessary to work for the highest economy at a pressure of about 1 in. mercury in the condenser, and this necessitates the use of steam jets and other contrivances as supplementary to the ordinary air pumps. To gain these high efficiencies also the steam turbine requires enormous amounts of condensing water. Practically the highest efficiency turbines could not be operated except near a large river or at the sea coast. When water cooling towers are necessary the thermal efficiency of the turbine is considerably diminished because of the higher pressure at which it becomes necessary to operate the condenser. In great central stations turbine driven the combined system therefore requires the discharge of the steam from the turbine about atmospheric pressure and therefore the limitation of thermal efficiency of the turbine to about 10 per cent. instead of 19. If the whole of the discharged heat, however, is required for, say, domestic heating in a city, then the combined efficiency will be very high. A system of electric lighting and town heat supply by steam engine thus requires sufficient boilers and a lower efficiency turbine to produce the united higher efficiency.

The internal-combustion engine differs from the steam turbine in this, that the thermal efficiency is not disturbed by the use of the exhaust gases for the purpose of heating. The best internal-combustion engines give from 30 per cent. to 35 per cent. brake efficiency, and after allowing for radiation, 60 per cent. of the original heat is still available between the heat of the water-jacket and the heat of the exhaust gases. In many works the heat of the exhaust is at present used for steam raising, and the steam so raised is applied to many purposes. Considered from this point of view the internal-combustion engine can be more readily applied to the combined system of producing heating and motive power than the steam engine.

NON-CONDENSING STEAM TURBINE AND STEAM HEATING FOR A CITY NECESSARY IF COAL CONSERVATION COMMITTEE'S AIM OF ECONOMY FOR POWER AND HEAT IS TO BE ATTAINED.

The principle of utilising the combined thermo-dynamic and steam heating efficiency has been long known, and I have already mentioned it in a lecture delivered in 1915.* I then stated: "Central stations could be established in which steam turbines were used for generating electric power, and where the exhaust steam from the turbine was discharged at a pressure above that of the atmosphere, so as to maintain the temperature above 100 deg. C. Such turbines would not give the thermal efficiency now obtained by Parsons, because they would lack the long expansion used by him in his largest and most efficient machines. The exhaust heat, however, could be used for manufacturing purposes and for household heating in a city, and a combined heating and thermal engine could thus be produced whose theoretical efficiency was 100 per cent.; the only loss would be that due to conduction during distribution, but heat supply for a city for heating houses and for doing low-temperature manufacturing work could be readily obtained from the waste heat of the steam turbines at the central stations. A large part of the heat necessary for comfortable life and industry could thus be obtained."

If we assume a steam heat and motive power station to be operated from boilers supplying the engines with steam containing 80 per cent. of the heat of combustion of the coal used on the boiler furnaces, then 10 per cent. deducted for motive power, leaves 70 per cent. of heat still available, and this, after distribution and use could certainly give an efficiency of 50 per cent.; that is, 35 per cent. of the original heat of the coal would be available for heating rooms and domestic cooking. The coal at present used for domestic purposes is about 36,000,000 tons per annum, and in its present use the combined efficiency for various purposes does not exceed 15 per cent. A steam power and heating system of this nature, if applied universally, would save one-half of the present fuel used for domestic purposes. The combined motive power and heating efficiency would be about 45 per cent. of the original heat of the coal burned in the furnace. This is a very much higher efficiency than could be expected with the proposed great super-stations indicated by the Government Report and the Electricity Supply Bill. Assuming a super-station to be able to generate electricity at the station equivalent to 20 per cent. of the heat of the combustion of the coal in the station boilers, the efficiency of transmission to the user could not be more than 90 per cent.; so that if electric current be consumed by the user for the purpose of producing heat in any form, the total heat available at the consumer's apparatus would be only 18 per cent. of the original heat of the coal consumed. From this it is

* Hawksley Lecture, 1915 (Institution of Mechanical Engineers).

evident that the idea of a super-station, fitted with turbines of the highest possible efficiency, does not lead to a high efficiency of thermal production. If an electricity generating station is seriously to attempt to supply heat as well as light and power, then the only practicable course appears to be the production of a turbine using steam through a limited expansion, so that high temperature steam becomes available for the heat distribution required in cities and factories for temperatures at about the boiling-point of water or somewhat above that point. That is, the exhaust steam from the engine should be used for the heat supply, and the electricity supply should be confined to light and power. In limited cases heat might be usually produced by electricity where very high temperatures are required; but for all ordinary heating work, undoubtedly much greater quantities of heat can be obtained by using the steam from the turbine without attempting to obtain the maximum thermal efficiency of power and electricity production. The use of such high-pressure steam turbines without vacuum would be very convenient for other reasons. The choice of the position for the central station would be greatly extended, as the enormous quantity of water required for condensation would be entirely dispensed with. Nothing would be necessary except the water required for evaporation and distribution. Apart from the condensing water difficulty, the very large turbines present mechanical difficulties which are avoided by the use of the smaller turbines.

Lord Kelvin's Proposal to Heat Rooms by Reversed Carnot Cycle Engine.

There is another method of obtaining heating from steam, gas or electrical power, which was advocated by Lord Kelvin more than thirty years ago. Lord Kelvin's proposal was as follows: The second law of thermodynamics shows that the thermal efficiency E, which is possible in a perfect heat engine, depends on the limits of temperature in such an engine between the maximum temperature of heat supply and the minimum temperature of heat discharge. If T be the maximum temperature and T_1 the minimum temperature, then the therma efficiency is $E = \frac{T - T_1}{T}$. If it be assumed that the engine is to work through a short temperature range, say, T = 309 deg. absolute, and T′ = 289 deg. absolute, then the maximum thermal efficiency is $\frac{20}{309} = \frac{1}{15 \cdot 45}$; that is the efficiency of the engine used as a heat engine. In virtue, however, of the property of a perfect heat engine being capable of being worked backwards, that is, in normal rotation, it can take heat from a source and convert a portion of it into work, and in the reverse rotation it requires work to be put in it, in which case the heat restored to the source is always greater than the heat equivalent of the motive power. In the particular case just given, a reversed engine working between these temperatures, which are 16 deg. C. and 36 deg. C., the heat equivalent of the electrical energy put into the engine is about 15½ times the energy put into it. By this device Lord Kelvin considered that with a reversible engine driven by motive power rooms might be heated and ventilated by the same machine; in the case given the air would be taken from the atmosphere at 16 deg. C., and delivered into the rooms at 36 deg. C., with an expenditure of heat of 1/15½ of the heat in the air delivered. This is a most interesting and fascinating application of the Carnot cycle. It has never been put into practice to my knowledge, and, of course, no machine could be designed to give the full efficiency of 15½ with these temperature limits; but even assuming only 50 per cent. efficiency of reversed transformation, we should still get nearly eight times the heat equivalent of the power used. Lord Kelvin's proposal would enable electricians to heat rooms to a moderate extent by interposing this machine, and using electricity to produce motive power and indirectly heat of air.

If we assume a gas engine consuming towns gas under present conditions of efficiency of production, distribution and use, as shown in Table II, then at eight times heat equivalent there would pass into the room 18·3 × 8 = 146·4 units of heat, that is, the heat of the air in the room would be nearly 50 per cent. above the total heat of the coal used at the gas works to produce the gas required to drive the engine at work reversing the Carnot cycle engine.

Making a similar assumption for electricity, we get 6·8 × 8 = 54·4 per cent. of the original heat of the coal used at the electricity generating station in the air of the room.

Lord Kelvin's idea opens an interesting field of work for heating and ventilating engines. The conclusions look as if they were wrong, but notwithstanding they are perfectly correct. The difficulties of application are practical, not theoretical. In my opinion the practical difficulties can be overcome.

Fuel Saving by Use of Water Power.

Further great savings of fuel are still possible by the utilisation of the water-power of our country. The amount of the possible water power has been somewhat understated. The investigation of the Board of Trade Committee on Water-Power Resources has shown that if necessary 1,500,000 h.p. could be obtained in the United Kingdom from the water at present running, without surrendering its power. It is to be remembered that this 1,500,000 h.p. to be obtained from water can be produced with our water-power supplies continuously during the whole 8,760 hours which form a year. That is, compared to steam and gas power, which is not generated continuously for more than half the time, the water-power would produce an equivalent of 3,000,000 h.p. instead of 1,500,000 h.p. By using our water power we could add 3,000,000 h.p. to the work of the country without consuming any additional coal.

Conclusions.

From the preceding discussion it will be seen that I do not accept the conclusion of the Coal Conservation Committee that it is desirable to substitute the electric generation and distribution of power, light and heat, by means of great super-stations for the existing means of supply, consisting of smaller generating stations, works driven by steam engines on the premises, turbine or reciprocating, and internal-combustion engines supplied by towns gas, producer gas, oil and tar. The separate generation of power, for example, by internal-combustion engines, at present gives higher economies than any steam engines, however large, and the saving of many million tons per annum in power production may as well be claimed for gas engines as for the proposed super-stations.

The values for gas are more favourable than those for steam in any form, and if we are extravagantly to imagine the complete suppression of all motive power but one, then promises as large as are justified for electricity can also be made for internal-combustion. Such promises however, are dependent on the possibility of replacing large amounts of capital at present sunk in separate motive-power installations. Such replacements do now take place during the ordinary development of the country by healthy competition between rival means of producing power. The United Kingdom has progressed rapidly by free competition between steam power in all its forms, internal-combustion in all its forms, and even in the application of our limited water power. The present competition between gas and steam has caused the rise in thermal efficiency of internal-combustion engines from 16 per cent. in 1876 to 30 per cent. to 35 per cent. in 1920, and it will lead in the near future to 45 per cent. as a maximum.

During the same period steam has risen from about 8 per cent. to 20 per cent., the highest present efficiency of the best large steam turbines at full load, and the efficiency may rise in the near future to 28 per cent. in the view of Sir Charles Parsons.

In my view it is desirable that the development of power and light generation should freely proceed in competition, and doubtless considerable economies can be effected over the existing results shown by the coal controller's figure. The Coal Conservation Committee are quite wrong in considering that any advantage to conservation can arise from the use of electricity to produce heat by the existing means. Great loss must follow such use, as I have shown. If heat supply is to be included in the electricians' programme, then the present high efficiency turbines must be abandoned and generation and distribution of power, light and heat, effected by means of exhaust steam or to some extent by Lord Kelvin's reversed Carnot cycle. Such schemes, however, are very much in the future in view of the very high efficiencies at present given by the coal-gas industries for combined services of heat, light and power. And it is to be remembered that the efficiencies in the gas industry will now rise rapidly in view of the dearness of coal.

In my view in the next ten years we may expect the general power consumption of coal to fall from 4 lb. per brake horse-power hour to under 2 lb. per brake horse-power hour, not by the extension of electric generation and use only, but by that extension as one element combined with the increased application of economical internal combustion engines and the improvement in steam boiler and town gas and gas producer efficiency.

Gas and electricity have large uses still open to them in generating and distributing power, but it is undesirable that either should artificially displace the other by the uninformed decision of a Government Committee or a Bill in Parliament.

THE HARDENING OF SCREW GAUGES.*

The Hardening of Screw Gauges with the Least Distortion in Pitch. (Referring to Water-Hardening.)

By the late Wilfrid J. Lineham, of the Goldsmiths' College, London, Member.

(Revised by Mr. G. T. White, of the Goldsmiths' College, London.)

In the hardening of screw gauges at Goldsmiths' College it was required to find a means of quenching the steel after heating so that the distortion along the pitch line should be reduced to a minimum. The work was being done under the scheme inaugurated and supported by the London County Council Education Department for war purposes.

The first law of hardening (known for many years) asserts that sudden quenching after heating retains the steel in the condition that prevailed at the quenching temperature.

The second law of hardening (of much more recent discovery) states that quenching, while crossing an arrest or recalescence point, produces the least amount of distortion, and it is one of the purposes of this paper to endeavour to prove the truth of this law. A second reason for the paper is to offer the author's results to other screw-gauge manufacturers for their immediate assistance.

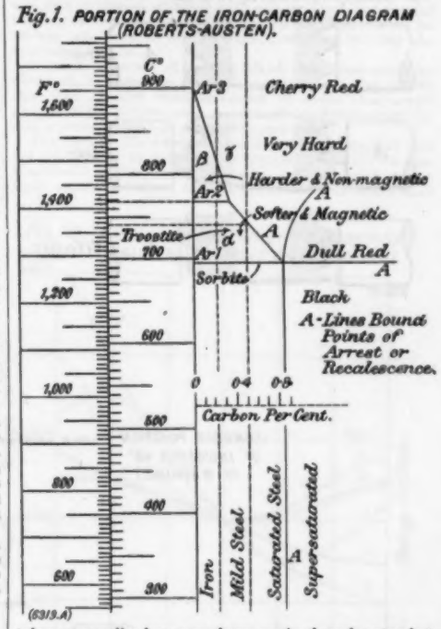
The second law had already been used by other investigators and practically applied with material success, but the author was unaware of the exact researches that have led to the adoption of fixed temperatures. The Wild-Barfield process he believed to be the first practical example, the principle of which is to use the change in magnetic properties of wrought iron or steel when passing from the β to the α state to indicate the temperature at which to quench. Reference to the Roberts-Austen diagram, Fig. 1, shows this to occur along the Ar2 line, temperature 765 deg. to 770 deg. C. (1,409 deg. to 1,418 deg. F.)

The Horstmann Brothers arrived at a similar result by quenching at 700 deg. C. (1,292 deg. F.), which is the temperature of the eutectoidal line Ar1. The screw gauges they manufactured were produced, they said, with no alteration in pitch, but a slight swelling always occurred in diameter, which was lapped down afterwards. They kindly communicated their method to the author, who thereupon decided to make his own investigations, the results of which are now set forth.

The author's first-sought ideal was a quenching temperature which would produce no distortion whatever, but it will be seen that this has not been achieved, nor does it seem likely that anything more than a minimum distortion can be arrived at. The Ar1 line for the use of the second law appeared to have manifest advantages over that at Ar2 because of its constancy of temperature over a large range of carbon percentages; and it seems reasonable to expect that steels of any carbon content will act in the same manner when cooling across this line, if all are free from impurities.

Before the war the manufacture of screw gauges was confined to the use of high-carbon steel, say, from 0·85 per cent. to 1·2 per cent. carbon, which was usually left unhardened, on account of the difficulties caused by distortion on quenching. The making of hardened screw gauges had been practised to a very limited extent before 1914, the correction after hardening being obtained by the use of laps of cast-iron or boxwood. The method

Fig. 1. PORTION OF THE IRON-CARBON DIAGRAM (ROBERTS-AUSTEN).



taken generally has now been revived and extended, and is the only one followed at the present time, so a short description will be useful in order that the author's intentions may be understood.

Assuming that the gauge can be hardened with so little change that the pitch tolerance, plus or minus, is not exceeded, which it will be shown can be done, the process of making a gauge involves, first, the accurate screwing of the blank, and then hardening the screwed piece.

The first was carried out in a lathe accurately corrected in pitch by a cam-bar. The screwing tool, known as a form tool, was of disc shape and supplied with chasing teeth on its circumference. Two of these "form chasers" were used, both being quite accurate in pitch and of perfect sectional contour for the thread to be cut. One was used to rough out the gauge screw to about half or two-thirds the thread depth; and the other, very carefully adjusted in position, to finish the thread correct on core, crest and effective diameters and full form. Constant measurement was, of course, necessary, but as the lathe slides were provided with micrometer discs, rapid and almost automatic manufacture was soon secured. The intention of the author at this stage of the work was to just clean up the gauge with a full-form cast-iron lap, accurately made from a top cut in the before-mentioned lathe. This method of lapping proved a failure, the abrasive clinging to the soft gauge and causing "scoring," so he fell back on the cutting tool itself for the accuracy demanded, assisted by the use of a very mild steel of 0·14 per cent. carbon for the blanks that cut with a polish. The object of the screwing operation was to produce a gauge that was perfect in all dimensions while yet in the soft state.

The next step was to harden. The hardening of screw gauges, and, indeed, some others, was performed in a cyanide furnace, made by John Wright, of Birmingham, which consisted of a rectangular cast-iron bath, covered and ventilated to remove the fumes, filled with sodium cyanide, and heated by coal gas and air, the latter being

* Paper read before the Institution of Mechanical Engineers, Friday, April 23, 1920.

fed at a pressure of 3 lb. per square inch. The cyanide, which melted at about 600 deg. C. (1,112 deg. F.) and boiled at or near 800 deg. C. (1,472 deg. F.), was maintained at 750 deg. to 770 deg. C. (1,382 deg. to 1,418 deg. F.) when in use, the temperature being indicated by a thermo-couple pyrometer. The gauges (of mild steel) were placed on trays suspended clear of the bottom of the bath and soaked from 10 minutes to 1 hour, according to size, or until they had acquired the requisite depth of case.

If a greater depth of case than 0·005 in. be required, packing the gauges with barium carbonate and bone black in closed boxes and soaking in a muffle furnace at about 850 deg. C. (1,562 deg. F.) must be resorted to, but the final heating should be completed in the cyanide bath.

It is possible to allow the cyanide bath to cool to the quenching temperature (supposing that to be exactly known) after the requisite soaking of the gauge, but the process absorbs much time and increases expense, and is not to be advised for continuous working. Also the temperature may be ascertained by the colour of the gauge, which may be taken as a very dull red, but this is not advisable. The author therefore installed, in addition to the cyanide bath, a Brayshaw salt-bath furnace, using "Pyromelt," and kept that furnace at the constant quenching temperature. This furnace was called the "Store furnace," for when a gauge had had its full time in the cyanide it was stored here at quenching temperature until its heat had evened up; and it was afterwards quenched at leisure. The quenching tank was close to the store furnace and of ample capacity, with inflow and outflow cocks.

The screw gauge was next measured for pitch and diameters. The diameter measuring machine has already been illustrated in the Proceedings,* and the mode of its use is merely suggested in Fig. 2, above, which shows the micrometer anvils at the moment of measurement.

The pitch-measuring machine, Fig. 3, was designed by the National Physical Laboratory and constructed at Goldsmiths' College. The drawing is somewhat diagrammatic in order to show the principle clearly. The gauge is supported between centres on the main or fixed casting. A movable carriage supports an indicator on the left and a micrometer on the right, being always pressed leftward by means of a weight. The indicator carries a stylo, which engages with the screw thread, and a pointer in connection therewith, whose reading is multiplied so as to be in the region of one-millionth of an inch of sensitiveness. The micrometer abuts against the main casting and can be read to 0·00001 of an inch, and very rapid charting of screw errors can be obtained.

After hardening, it was found that the screw pitch had not distorted beyond the tolerance, plus or minus, if precautions had been taken such as suggested later. The diameters, however, had increased, at least the core and crest were larger, but the effective surface was often unchanged. The operation of lapping followed, three laps, Fig. 4, being used; but the enlargement being only about 0·0001 in. to 0·0003 in. in diameter, the amount of lapping was very little. Naturally the operation was of a delicate character, and was the particular part of the whole process that most held up delivery; many gauges were spoilt in its exercise; but it is believed that the whole hardening process will yet be so perfected that only a full form cleaning lap will be necessary.

Finally, each gauge was examined by an optical lantern magnification of exactly 50 to 1, as already described in previous papers; and, of course, the pitch and the diameters at all three elements of section were thoroughly tested during the stages of manufacture and just before delivery, by a competent staff of examiners.

It will be said that if only a screw gauge could be made to travel through its various manufacturing steps in such a simple and well-oiled manner, the difficulties of screw-gauge making would be completely overcome. It is one intention of this paper to show that the difficulties of manufacture are being overcome by the adoption of definite scientific method, and there are strong and practically certain hopes of doing away with lapping altogether.

The crucial point of the manufacture is the hardening. Lathes have been specially built that will produce accurate pitch, and mild steel is being used that can be finished in those lathes with a polish. It will be shown that a quenching temperature can be found that only lengthens the pitch by 0·0002 in. over 0·7 in. of length, which is within the pitch tolerance, 0·0003 in., on such a length for inspection gauges of correct effective diameter.

Two remarkable examples of distortion are shown. The first, Fig. 5, was before treatment a cheese-shaped disc of 4¼ in. diameter by 1½ in. thickness, of common mild steel. It was heated in a coke fire and quenched in water, the operation being repeated about a thousand

* Proceedings, 1917, page 54, and Fig. 4, page 55.

Fig. 2. MEASUREMENT FOR DIAMETER. A.A.A. MICROMETER ANVILS.

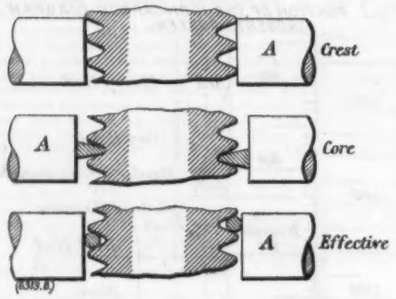


Fig. 4. LAPPING THE SEPARATE ELEMENTS OF A SCREW.

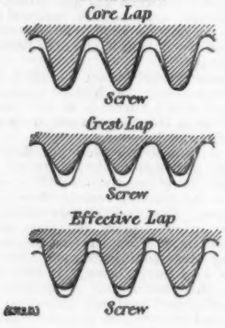


Fig. 5. A DISC OF MILD STEEL 4¼" DIAM AND 1½ THICK ORIGINALLY, WAS SWOLLEN AS SHOWN BY MEANS OF 1000 SUCCESSIVE HEATINS & QUENCHINGS

Original volume—21·23 cubic ins.
Final volume—31·60 cubic ins.

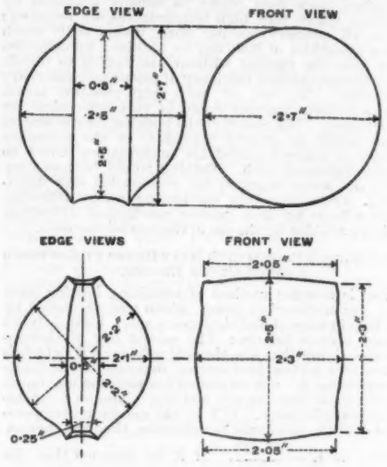
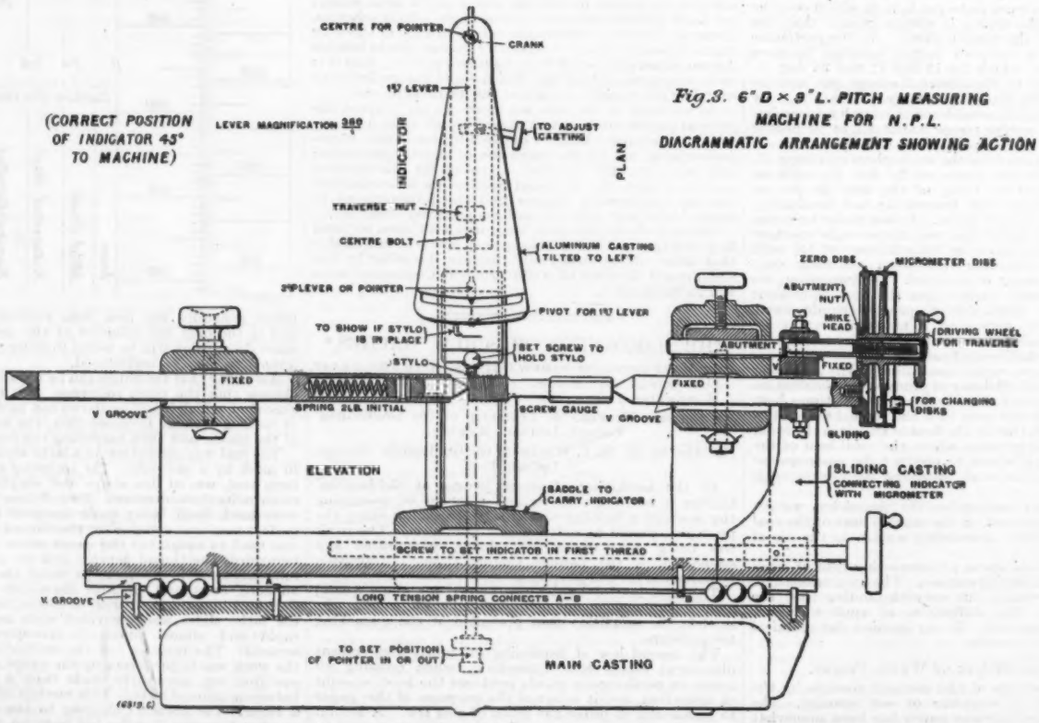


Fig. 6. A RECTANGULAR DISC OF MILD STEEL WAS SWOLLEN AS SHOWN BY MEANS OF 1000 SUCCESSIVE HEATINGS AND QUENCHINGS

Fig. 3. 6" D × 9" L. PITCH MEASURING MACHINE FOR N.P.L. DIAGRAMMATIC ARRANGEMENT SHOWING ACTION



times. The continued distortion has swelled the disc into an approximate spherical form, but that the volume is unchanged was ascertained by displacement measurement.

The second specimen, Fig. 6, was at first a rectangular disc, and here again the spherical form is attempted, the treatment being the same as in the first example.

These two specimens came to the author as a piece of exceptional good fortune, being presented by Mr. F. A. Thompson. Their history is: A garage boy required buckets of hot water at meal times and kept three of these pieces hot on coke fires, using which he pleased to heat the water by immersion, and continuing his unintentional experiments over a period of about a year.

The author commenced his experiments in April, 1918, by providing seven specimens for each experiment, the material being J and L steel of 0·14 per cent. carbon. Each specimen was ground and carefully surfaced by stoning the ends, and the dimensions were about $\frac{7}{16}$ in. diameter by 0·7 in. long. Previous experiments upon pieces of full-gauge shape showed the wisdom of using simple cylinders for the temperature tests so as to obtain symmetrical distortions.

One form of distortion resulting from hardening a cylindrical piece of steel was found to be a swelling or bulging at the ends, but the length, measured at the edges, remained very little changed indeed.

The experiments were begun without any clear notion of the form the distortions were likely to assume, and axial measurements were at first made, which proved to be wrong for the purpose required. Also the ends of the cylinders were not parallel to less than 0·0001 in., and the average dimension was taken in the hard and in the soft states respectively. When, however, the circumference was divided into three or four parts and marked, and the change of length taken at the marked positions only and afterwards averaged, quite consistent results were obtained, the figures fairly representing pitch-line distortions on a screw gauge.

Figs. 7 to 12, above, show, for six sets of experiments, changes of length in units of 0·0001 in. plotted on a base of quenching temperature.

Fig. 7 (April 5, 1918) is a record of the average change of length measured over the end surfaces, and contains the axial bulging. It was on this set that the bulge was first noticed, and from this time onward measurements were made on the edges only. The temperature of 700 deg. C. (1,292 deg. F.), however, is indicated as that of no distortion.

Fig. 8 (April 24, 1918). The distortions are all extensions, and 670 deg. C. (1,238 deg. F.) indicates least distortion. Several screws were hardened at this figure with success.

Fig. 9 (April 27, 1918). This curve was distressing. It seemed to show that there was no fixed law and that nothing would result from the labour. The figure 685 deg. C. (1,265 deg. F.) was taken as best, for the drop at 730 deg. C. (1,346 deg. F.) might not be trustworthy.

Fig. 10 (May 4, 1918). A good curve showing 700 deg. C. (1,292 deg. F.) to be decidedly the best temperature. Two specimens were quenched at 670 deg. C. (1,238 deg. F.) and are shown fairly to agree.

Fig. 11 (May 9, 1918). Another wavy curve, with minimum at 695 deg. C. (1,283 deg. F.).

Fig. 12 (May 11, 1918). There is here a minimum at 700 deg. C. (1,292 deg. F.), but also at three other temperatures.

The problem, which now appeared hopeless, suddenly cleared itself. It occurred to the author to plot all the curves on one sheet by superposition, as in Fig. 13, above, and this operation was at once fruitful in showing that the distortion, or as it may now be called, extension, had definite laws and was not the result of mere chance. Disregarding the first curve shown dotted, all cross at exactly one point, namely, 700 deg. C. (1,292 deg. F.), the recalescent point Ar1 of the equilibrium diagram.

The extension is, unfortunately, not obliterated, but it has a fixed and definite value of 0·0002 in., and is within the tolerance limits. It indicates a condition of stability, and if 700 deg. C. (1,292 deg. F.) be made the quenching temperature, this extension can be allowed for when cutting the screw.

Other parts of the curves show nothing but instability. The use of the position 700 deg. C. (1,292 deg. F.) therefore is calculated to assist correct manufacture, while all the other temperatures are unreliable. On that account, an attempt to find a stable temperature of maximum extension, for use when needed, was practically unsuccessful; for gauges quenched at 715 deg. C. (1,319 deg. F.) did not always extend well. A very important point is that the temperature must be found with accuracy, the range of stability being so very limited.

In Fig. 14 the distortion scale has been magnified and plotted for a range of 15 deg. ± of 700 deg. C. Maximum instability occurs at 715 deg. C. as well as maximum distortion, and in all cases temperatures below 700 deg. C. are safer than those above. A fair and safe latitude for quenching lies between 690 deg. C. (1,274 deg. F.) and 700 deg. C. (1,292 deg. F.).

The author found no difficulty in making sure of 700 deg. C. with the use of a platinum-rhodium thermocouple, a thermometer within the galvanometer-case giving warning of any change of temperature of the cold junction. Upon retesting the thermocouple after about six months' use it was found by the makers to be quite accurate. It now appears that the second law of hardening proposed at the commencement of this paper is proved so far as the line at Ar1 is concerned, and could no doubt be proved for other arrest points.

In the early stages of this research measurements of distortion on diameter were made, which always showed an increase of about 0·0001 in. to 0·0003 in., but the purpose of the research being the measurement of length distortion in screw gauges, and time being pressing, diameter measurements were not proceeded with.

Before obtaining the pyrometers, which were not in use before April 5, some experiments were made on a colour scale extending through—Bright red; Grey just appearing (due to freezing of the cyanide); Full grey; Dull red; Black just appearing; Mid black; Full black; the specimen being held in a half light. The results pointed to a best temperature between dull red and black just appearing. Some experimenters have further perfected the colour test, but the author considered the pyrometer method undoubtedly superior, which, with his system of two furnaces could be practised by a somewhat unskilled operator. Further experiments are needed on ring gauges, which have laws of their own as regards diametric distortion, and the author had hoped to make experiments on other gauge shapes.

It has not been exactly discovered what the first stages of distortion assume, for in the boy's experiments the diameters are all decreased, though it is certain they increased at first. It was believed that a barrel shape was first produced, coupled with end swelling, but careful test has shown a festoon shape on the rim, and it must be always remembered that Nature insists on keeping the volume constant.

Instead, however, of waiting till all these facts could be obtained, it appeared wiser to make known the results that had already been acquired, in order that screw gauges might be produced more easily and accurately by every manufacturer in a time of great need.

The fact of the emulsive constitution of steel at Ar1 led the author to believe that gauges quenched on this line would not be thoroughly hard. He was glad to say that, on the contrary, he had found them in every case to be glass hard. It must not be forgotten that the process of hardening by casing in cyanide produces a high-carbon steel at the surface, while the interior remains in the mild state, and this may have something to do with it.

The most important of the conclusions arrived at in this paper are:—

(*a*) The second law of hardening is essentially proved.

(*b*) A temperature of minimum distortion that can be relied upon is 700 deg. C. (1,292 deg. F.).

(*c*) No variation is allowable above 700 deg. C.

(*d*) An allowance of 10 deg. below 700 deg. C. is practically permissible.

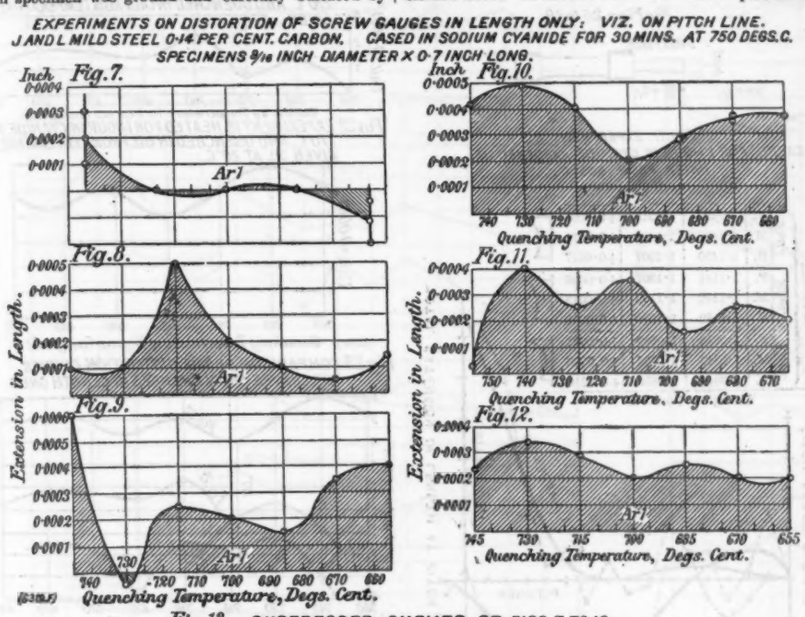
The author's thanks are due to: The London County Council Education Department, who provided the apparatus, and allowed of its use; to Mr. E. W. Eager, the author's works manager on screws, who prepared and tested the specimens; and to Mr. F. A. Thompson, who gave the swelled specimens; also to many manufacturers, who very kindly assisted the demands of the investigations.

THE HARDENING OF SCREW GAUGES WITH THE LEAST DISTORTION IN PITCH. (REFERRING TO OIL HARDENING).

By the late WILFRID J. LINEHAM, of the Goldsmiths College, London, Member.

(Revised by Mr. G. T. WHITE, of the Goldsmiths' College, London.)

THE first paper was complete in itself. A quenching temperature of 700 deg. C. (1,292 F.) was indicated as the position of smallest stable distortion in length under the conditions carefully stated. There were six sets of


EXPERIMENTS ON DISTORTION OF SCREW GAUGES IN LENGTH ONLY: VIZ. ON PITCH LINE.
J AND L MILD STEEL 0·14 PER CENT. CARBON. CASED IN SODIUM CYANIDE FOR 30 MINS. AT 750 DEGS. C.
SPECIMENS 9/16 INCH DIAMETER X 0·7 INCH LONG.
Fig.7.
Fig.8.
Fig.9.
Fig.10.
Fig.11.
Fig.12.
Inch.
Ar1
Extension in Length.
Quenching Temperature, Degs. Cent.

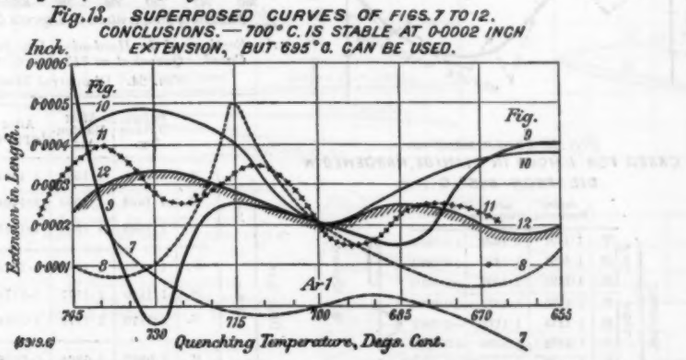


Fig.13. SUPERPOSED CURVES OF FIGS. 7 TO 12.
CONCLUSIONS.— 700° C. IS STABLE AT 0·0002 INCH EXTENSION, BUT 695° C. CAN BE USED.
Inch.
Extension in Length.
Ar1
Quenching Temperature, Degs. Cent.

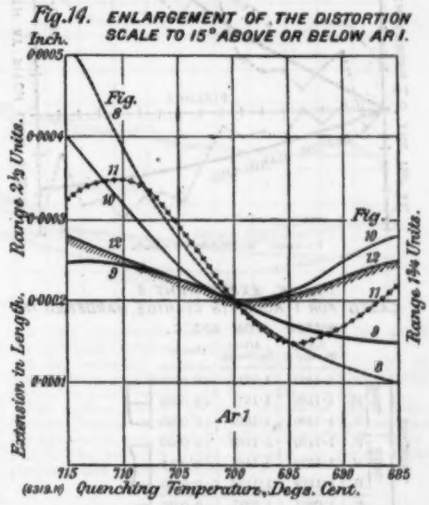


Fig.14. ENLARGEMENT OF THE DISTORTION SCALE TO 15° ABOVE OR BELOW AR 1.
Inch.
Range 2½ Units.
Range 1½ Units.
Extension in Length.
Ar1
Quenching Temperature, Degs. Cent.

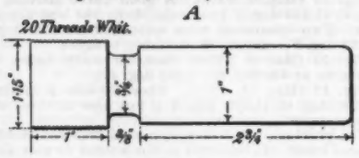
experiments (Experiments 1 to 6), and the time of casing in cyanide was about half an hour, calculated to produce a case of about 0·003 in. It should be noted that the experiments did not actually prove more than was claimed in the paper, and nothing was made evident regarding any other possible conditions. Continuing his experiments, the author subsequently found other important results, which are now described in this second paper.

Experiment 7 (*May* 22, 1918).—An actual screw gauge was prepared to the dimensions in Fig. 15A. This was screwed in the lathe to 0·0002 in. minus in total pitches and to the diameters shown in the chart, Fig. 16. It was cased in barium carbonate and bone black for 2 hours at a temperature estimated at 800 deg. to 850 deg. C. (1,472 deg. to 1,562 deg. F.). It was immediately afterwards transferred to the cyanide bath, which stood at 770 deg. C. (1,418 deg. F.), allowed a quarter hour to even up, and another quarter to lower to 695 deg. C. (1,283 deg. F.), at which temperature it was quenched in water at about 15 deg. C. (59 deg. F.).

The results of this test are shown in Fig. 16, from which it will be seen that the length increased by 0·0011 in., while the diameters were enlarged by about 0·0022 in., the festoon shape being definitely formed on the rim.

Fig. 15. GAUGES USED IN EXPERIMENTS.

For Figs. 16 to 19, 24, 24a, 25 and 25a.



For Figs. 26 to 29.

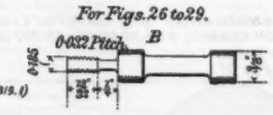
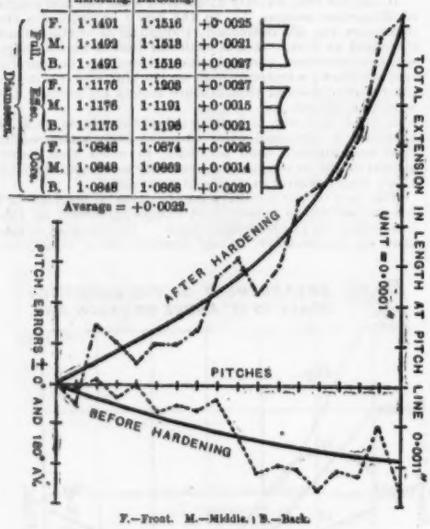


Fig. 16. EXPERIMENT 7.
CASED FOR 2 HOURS IN BOX. HARDENED IN WATER FROM 695° C.

		Before Hardening.	After Hardening.	Change.
Diameters. Full.	F.	1·1491	1·1516	+0·0025
	M.	1·1492	1·1513	+0·0021
	B.	1·1491	1·1518	+0·0027
Effec.	F.	1·1176	1·1203	+0·0027
	M.	1·1176	1·1191	+0·0015
	B.	1·1175	1·1196	+0·0021
Core.	F.	1·0848	1·0874	+0·0026
	M.	1·0848	1·0862	+0·0014
	B.	1·0848	1·0868	+0·0020

Average = +0·0022.



F.—Front. M.—Middle. B.—Back.

Fig. 17. EXPERIMENT 8.
CASED FOR 1 HOUR IN CYANIDE. HARDENED IN WATER FROM 695° C.

		Before Hardening.	After Hardening.	Change.
Diameters. Full.	F.	1·1490	1·1515	+0·0025
	M.	1·1490	1·1501	+0·0011
	B.	1·1490	1·1507	+0·0017
Effec.	F.	1·1161	1·1207	+0·0026
	M.	1·1182	1·1195	+0·0013
	B.	1·1182	1·1200	+0·0018
Core.	F.	1·0848	1·0869	+0·0021
	M.	1·0849	1·0855	+0.0006
	B.	1·0849	1·0859	+0·0010

Average = +0·0016.

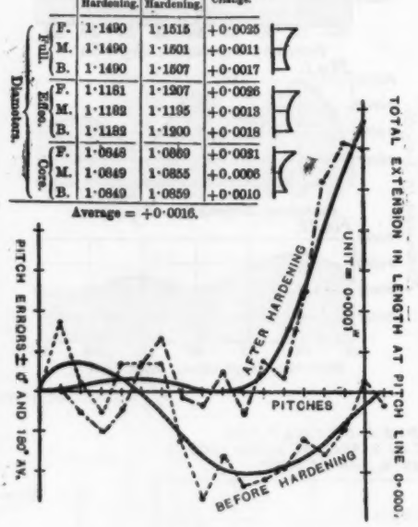


Fig. 18. EXPERIMENT 9.
CASED FOR 1 HOUR IN CYANIDE, HARDENED IN WATER FROM 685° C.

		Before Hardening.	After Hardening.	Change.
Diameters. Full.	F.	1·1489	1·1511	+0·0022
	M.	1·1489	1·1511	+0·0022
	B.	1·1490	1·1510	+0·0020
Effec.	F.	1·1170	1·1190	+0·0020
	M.	1·1170	1·1184	+0·0014
	B.	1·1172	1·1192	+0·0020
Core.	F.	1·0861	1·0877	+0·0016
	M.	1·0855	1·0872	+0·0017
	B	1·0858	1·0872	+0·0014

Average = +0·0017

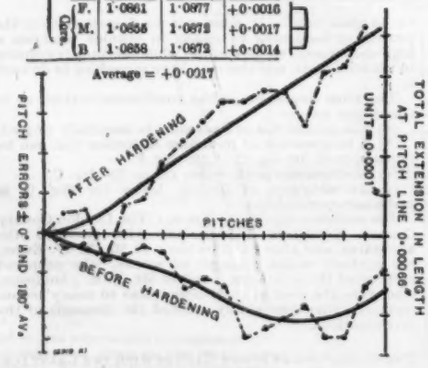
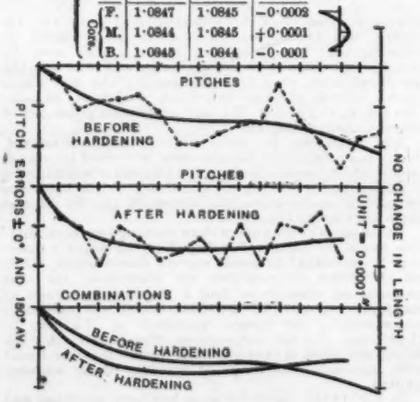


Fig. 19. EXPERIMENT 10.
CASED FOR 1 HOUR IN CYANIDE, HARDENED IN OIL FROM 695° C

		Before Hardening.	After Hardening.	Change.
Diameters. Full.	F.	1·1491	1·1492	+0·0001
	M.	1·1491	1·1492	+0·0001
	B.	1·1491	1·1492	+0·0001
Effec.	F.	1·1172	1·1173	+0·0001
	M.	1·1175	1·1173	−0·0002
	B.	1·1172	1·1173	+0·0001
Core.	F.	1·0847	1·0845	−0·0002
	M.	1·0844	1·0845	+0·0001
	B.	1·0845	1·0844	−0·0001

Average = 0.



It is evident that the extension of 0·0002 in. found in the previous paper is only correct for gauges cased for half-an-hour in cyanide and does not apply to the treatment under present consideration.

Experiment 8 (*May* 24, 1918).—A similar screw gauge was heated for 1 hour in cyanide, and afterwards quenched at 695 deg. C. in water Fig. 17). The extension is now 0·0007 in., and the increase in diameter about 0·0016 in. It should be noted that the gauge has a long screw and the experiment rather suggests that length is a factor in total extension.

Experiment 9 (*May* 24, 1918).—This gauge is another repetition of that in Fig. 15A, and the results of cyanide casing for 1 hour with a quenching from 695 deg. C. in water are given in Fig. 18. The extension in length, 0·00066 in. is only a trifle better than the last gauge: While the diameter change, averaging 0·0017, is about the same, but it is much more variable. The general result of experiments 8 and 9 is to suggest a stable extension of 0·0007 in. under the exact conditions given.

Experiment 10 (*May* 25, 1918).—The same form of gauge, after heating, was cooled in cold machine oil,

Fig. 20. EXPERIMENT 11. HEATED FOR 1 HOUR IN CYANIDE AT 770°C., AND QUENCHED FROM TEMPERATURES GIVEN IN OIL AT 22° TO 29°C.

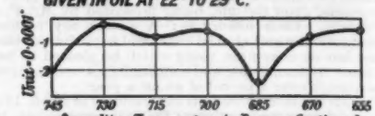


Fig. 21. EXPERIMENT 12. HEATED FOR 1 HOUR IN CYANIDE AT 770°C., AND QUENCHED IN OIL FROM TEMPERATURES GIVEN.

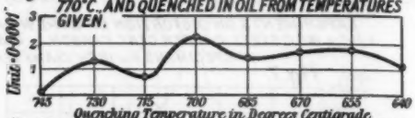


Fig. 22. EXPERIMENT 13. HEATED FOR 1 HOUR IN CYANIDE AT 770°C. AND QUENCHED IN OIL FROM TEMPERATURES GIVEN. OIL AT 20°C.

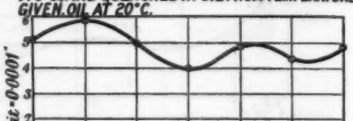
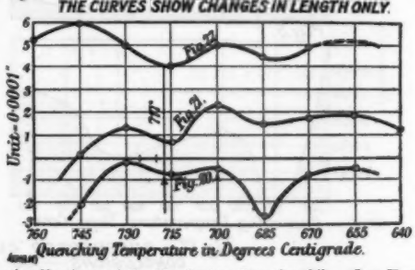


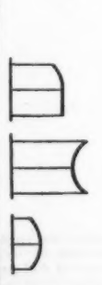
Fig. 23. COMPARISON OF THE DISTORTION CURVES. THE CURVES SHOW CHANGES IN LENGTH ONLY.



Applications of the Hardening Law for Oil. One Hour Cased. Quenched at 717 deg. C. (1323 deg. F.).

FIG. 24. Diametral Distortion.

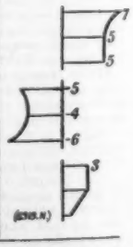
—		Before Hardening.	After Hardening.	After Lapping.
Diameters. Full.	F.	1·1495	1·1500	1·1494
	M.	1·1498	1·1504	1·1494
	B.	1·1498	1·1504	1·1494
Effec.	F.	1·1171	1·1180	1·1174
	M.	1·1170	1·1177	1·1174
	B.	1·1170	1·1179	1·1174
Core.	F.	1·0862	1·0864	1·0858
	M.	1·0861	1·0864	1·0858
	B.	1·0862	1·0864	1·0857



Further Applications.

FIG. 25. Diametral Distortion.

—		Before Hardening.	After Hardening.	After Lapping.
Diameters. Full.	F.	1·1492	1·1499	1·1495
	M	1.1494	1·1499	1·1495
	B.	1·1495	1·1500	1·1494
Effec.	F.	1·1178	1·1173	1·1175
	M	1·1177	1·1173	1·1174
	B.	1·1178	1·1172	1·1172
Core.	F.	1·0853	1·0856	1·0853
	M	1·0853	1·0856	1·0853
	B.	1·0855	1·0856	1·0851



and the chart in Fig. 19 shows an essentially unaltered condition on all dimensions. The quenching temperature was 700 deg. C. (1,292 deg. F.). The use of oil as a quenching medium was entirely due to the initiative of Mr. E. W. Eager, and the result is indeed remarkable.

The hardness was tested with a new file, and no kind of scratch was obtainable. The author's attempts to eliminate lapping seemed reasonably in sight, and it was decided to attack the subject afresh by the use of specimens as in the first paper.

Experiment 11 (*May* 27, 1918).—Seven cylindrical specimens were provided, each about $\frac{3}{4}$ in. diameter and 0·7 in. long, of J and L steel, 0·14 per cent. carbon. They were heated in cyanide for 1 hour, and quenched from the temperatures given in Fig. 20 in oil at from 22 deg. to 29 deg. C. (72 deg. to 84 deg. F.). The mode of measurement was as described in the first paper, and warp a gauge, just as a shaving taken off timber will do, by releasing internal stress.

The remaining diagrams, Figs. 26 to 29, which show the final combinations only for the smaller gauge, illustrated in Fig. 15B, each exhibit distinctive features worthy of study. What is claimed generally is that screw gauges can now be produced, which if screwed to correct pitch, in a lathe having a correcting bar, and to diameters which are two-thirds of the limit below high and one-third above low, and hardened by quenching from 717 deg. C. in oil, will not need to be lapped at all, but merely polished with a little rouge or other fine powder. The advantage is a great saving in time and cost, both important in war-time, for two-thirds of the cost of a gauge often lies in the lapping. Even if lapping has to take place it need not be more than the very smallest amount, but the great majority of the gauges should not be lapped at all. The best ideal is to try and retain the perfect work that a good lathe produces, for lapping nearly always distorts. The only advantage that lapping possesses lies in its partial elimination of bad periodic errors, but these again can be overcome in the lathe itself.

The conclusions drawn from this paper are :—

1. Hardening screw gauges in oil, after casing in cyanide, can be performed with less distortion than if water is the quenching medium.

Fig. 24a. APPLICATIONS OF THE HARDENING LAW FOR OIL. 1 HOUR CASED. QUENCHED AT 717° C. CURVES OF PITCH ERROR.

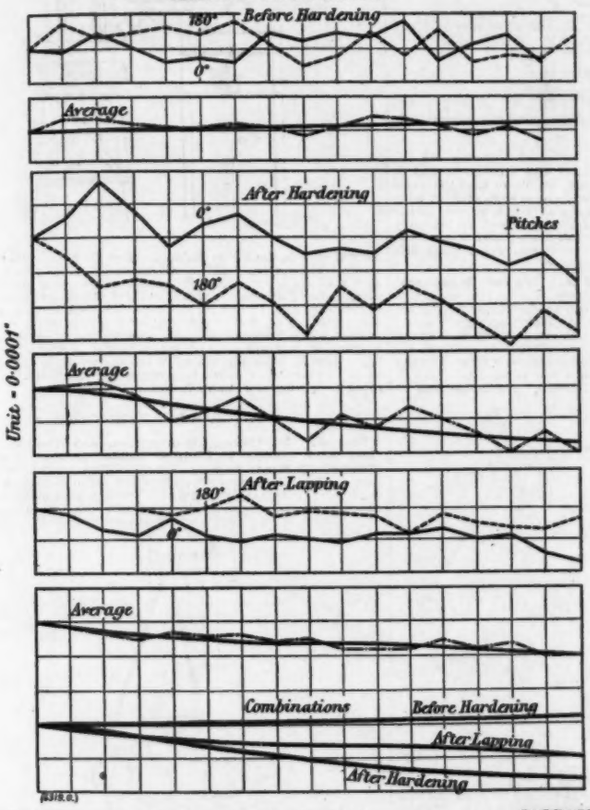
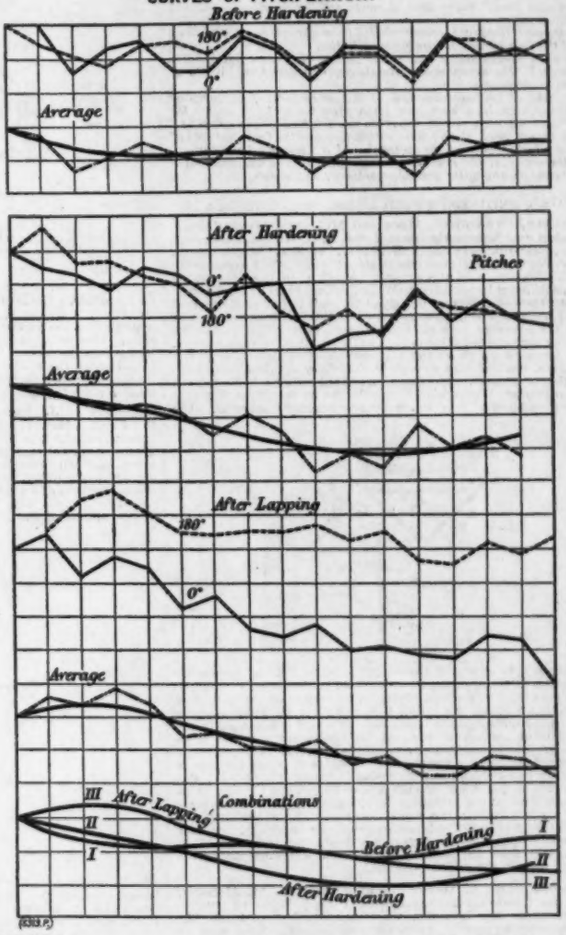


Fig. 25a. FURTHER APPLICATIONS. CURVES OF PITCH ERROR.



the distortions were taken on length only. The hardness in this and the following experiments was excellent. In every case there is a decrease in length, but the amount is generally very small. The best temperatures are between 700 deg. C. and 730 deg. C. (1,292 deg. F. and 1,346 deg. F.).

Experiment 12 (*May* 28, 1918).—The distortions are all extensions of Fig. 21, and their amounts somewhat larger on the whole, though not really great. No good law is yet apparent.

Experiment 13 (*June* 5, 1918).—The distortions are again plus, Fig. 22, but they are much larger than in the two previous cases. This the author believed to be entirely due to the fact that the material was unannealed beforehand, while in experiments 11 and 12 the material was annealed. It is found that with annealed gauges the first two experiments can be repeated nearly every time, and experiment 13 may be viewed as abnormal, although it has a certain value in the way of comparison, as follows :—

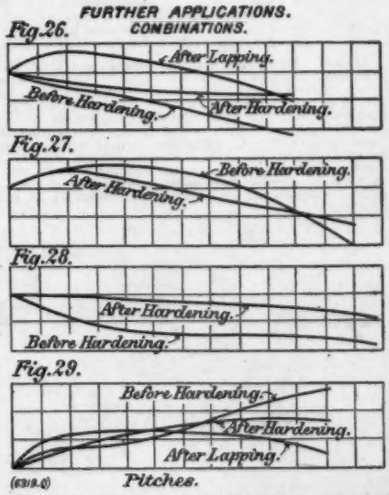
In Fig. 23 the three curves are compared on a common base. No crossing law can be found as in the first paper, but a curious "stream-line" effect is noticeable, and a minimum or dip in the curves at the temperature of 717 deg. C. (1,323 deg. F.). This temperature is therefore indicated as that of least distortion on quenching, and is that which the author definitely adopted in screw-gauge manufacture.

Applications of the hardening law for oil are next given in Figs. 24 to 29. The charts, Figs. 24 and 25, and diagrams, 24A and 25A, show at a glance the results of the application of the quenching temperature of 717 deg. C., both on diametral and pitch distortion.

In Fig. 24, the respective gauge in Fig. 15A, page 596, was screwed without serious error and was reduced in total length by hardening to the extent of 0·0001 in. As the diameters had been turned a little large, lapping had to be used, but the effect was good, and the final gauge was only about 0·00005 in. short.

In Fig. 25A the three curves at bottom of diagram show only small changes due to hardening and lapping. The most serious change is that due to lapping, which has caused a difference between the readings at 0 deg. and 180 deg. of the gauge circumference. This clearly indicates that a small thickness of surface removed may

Fig. 26. FURTHER APPLICATIONS. COMBINATIONS.



2. The temperature at 717 deg. C. (1,323 deg. F.) is the best heat for quenching at.

3. By screwing gauges to accurate pitch and to diameters at two-thirds below high limit and one-third above low limit, lapping can be dispensed with.

The author tenders his best thanks to the London County Council Education Department, who provided the apparatus, and allowed of its use, and to Mr. E. W. Eager, the author's works manager on screws, who prepared and tested the specimens.

CANADIAN INDUSTRIES EXHIBITION, LONDON.—A Canadian Industries Exhibition is being opened at the Royal Agricultural Hall on June 3 next by the Hon. Sir George H. Perley, K.C.M.G., High Commissioner for Canada. This exhibition, which remains open for 14 days, consists entirely of Canadian products and includes the following industries: Iron and steel, minerals, hand tools, transmission machinery, agricultural machinery, tin and enamel ware, sheet metals, building materials, &c. The exhibition will be open to the trade free, from 11 a.m. to 9 p.m., and to the general public from 2 p.m. to 7 p.m. Tickets may be obtained on application to the Manager, 43, Essex-street, Strand, W.C. 2.

LANGUAGES SPOKEN IN BRAZIL.—Foreign languages, states H.M. Commercial Secretary at Rio de Janeiro, are read and spoken in Brazil in the following order: French, Italian, English, German and Spanish, the last-named being a very bad fifth. This language is, of course, understood by all the educated classes, but it is neither read nor spoken. The leading bookseller of Rio de Janeiro has stated that he did not sell one-hundredth part of the literature in Spanish that he did in German, and sales in the latter language are naturally somewhat restricted. It is hoped that trading concerns dealing with Brazil, or desiring to do so, will realise that it is the literal truth that Spanish will not serve as the language medium. The bookseller alluded to above added that if the sale of a certain publication submitted to him were of interest to him he would sooner have it in English than in Spanish, if it were a choice between these two languages.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

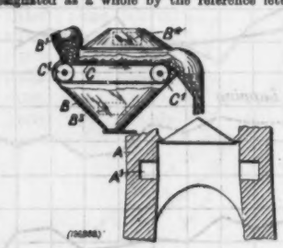
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

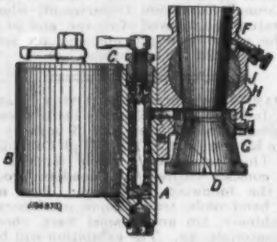
GAS ENGINES, PRODUCERS, HOLDERS, &c.

136,868. The Firm, Mers and McLellan, Westminster, London and Newcastle-upon-Tyne, A. C. Michie, Jesmond, Newcastle-upon-Tyne, and E. G. Weeks, Monkseaton. Low-Temperature Fuel Distillation. (1 *Fig.*) November 20, 1918.—According to the present invention, in the process for the continuous low-temperature distillation of fuel by the passage of superheated steam or hot gases through it (without external heat) wherein during the process of distillation fresh charges of fuel are admitted into the retort, there is provided means for heating each charge of incoming fuel, before it is fed to the retort, to a temperature above the temperature of condensation of the distillate, but not high enough to cause any appreciable decomposition of the fuel. The upper end of the retort A is illustrated, and constructed conveniently in relation to the retort is a preheater designated as a whole by the reference letter B. The



preheater may be of any convenient construction, and preferably comprises an outer casing in which is an endless band C mounted on rollers C1. At one end of the upper surface of the band, and projecting through the casing B is a hopper B1 which supplies coal to the surface of the band, and by which it is carried in the direction of the arrow towards an outlet, from which it is discharged on to the feeding cone of the retort A. The preheater is heated with gases which may be steam or waste furnace or other hot gases which enter the casing B through the port B2, and are removed therefrom through a port B3. Thus the fuel in its passage through the preheater B becomes heated to a temperature which prevents the condensation on it of the products distillation which it meets on entering the retort A, the said products being conveniently removed through a duct A1 in connection with any convenient form of extractor apparatus located outside the retort. (*Sealed.*)

136,973. B. A. Davey, London, and H. M. Hobson, Limited, London. Carburettors. (1 *Fig.*) March 13, 1919.—According to this invention, an "emulsion" of fuel and air, that is to say an extremely rich mixture, is supplied to an annular space around the air passage or mixing chamber, and enters the latter through a slit in the wall of the passage, one part of which can be moved towards or away from the other. A known means is employed for producing the rich mixture or "emulsion," comprising a fuel well A fed from the float chamber B, through which air, entering at C, bubbles, the "emulsion" issuing at D.



This "emulsion" is supplied to an annular recess E formed at the bottom of the main part F of the mixing chamber. Into this main part F screws an intake G, between the upper edge of which and the corresponding lower edge of the mixing chamber is left the slit H through which the "emulsion" enters the air passage J through the mixing chamber. By rotating this intake G, the depth of the slit H can be varied and the amount of "emulsion" supplied can be adjusted. The adjustment of the intake G may be capable of operation from a distance, or it may be interconnected with the throttle, to give the required results. (*Sealed.*)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

136,422. H. Laughton, Sutton Coldfield. Belt Gearing. (3 *Figs.*) March 22, 1919.—The invention relates to power-transmission belt gearing, and is applicable in cases where one of the two belt pulleys is small in proportion to the other, and in which two jockey pulleys are disposed on the outer sides of the belt near the small main pulley, and said jockey pulleys are carried by an oscillating lever which will permit of a self-adjustment of said pulleys in the plane of rotation of the main pulley. According to the invention, the jockey pulleys are carried by a lever pivoted to a fixed point disposed on the opposite side of the main pulley to that on which the jockey pulleys are situated. The two jockey pulleys A and B are mounted on axles carried by a preferably-curved lever C, which is mounted on a fixed axle D, disposed parallel to the axis of the small main pulley E, at a point which is on the opposite side of the pulley E to that on which the jockey pulleys A and B are situated. The space between the jockey pulleys A and B, through which both sides of the belt F is carried so as to draw them together as shown, is thus in a direct line with the axis of the main pulley E and the axle D. One jockey pulley B is adjustable on the lever C relatively

Fig. 1.

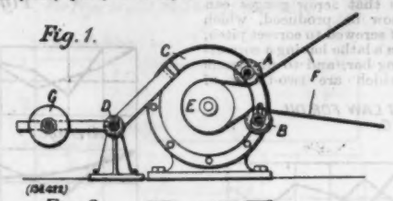
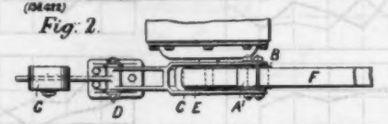
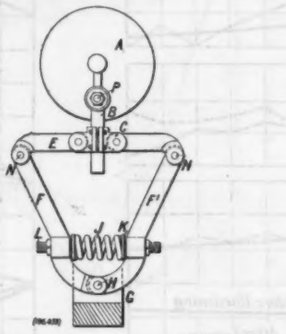


Fig. 2.



to the other. The lever C is provided with a counterweight G, so that it is balanced, and is made double so that the axles which carry the jockey pulleys A and B are supported at both ends. The jockey pulleys A and B can adjust themselves to the movements of the belt F due to varying loads, and the tendency is to tighten the belt grip on the small main pulley E when the load is suddenly increased, whilst maintaining a regular belt tension when the load is constant. (*Sealed.*)

136,458. J. Sheane, Wicklow. Power Hammers. (5 *Figs.*) May 16, 1919.—The invention relates to power hammers of the type in which the tup or block is actuated from a disc crank through the medium of pivoted spring-controlled levers in which construction a yielding stroke is obtained as the tup strikes the object to be operated on. Pivoted levers E, F, F1, are in the form of an inverted equilateral triangle secured to the tup G by a pivot joint H at the apex and to the disc crank A at the middle of the base of the triangle. The connection to



the disc crank A is effected by a yoke C embracing a downwardly-hanging rod B pivoted at P to the crank A. The levers E on either side of the yoke C are pivoted at N, N, to the side levers F, F1, each of which is curved at its lower end so that the two together form a bow with a pivot joint H at its centre. Within the bowed portion of the levers F, F1, is a spring I, with adjusting means connected thereto, consisting of caps K, and adjusting screws L engaging in tapped holes in the levers F, F1. (*Sealed.*)

136,347. Sir A. Herbert, Whitchurch, and P. V. Vernon, Keresley. Lathes. (5 *Figs.*) January 23, 1919.—The invention relates to the beds of lathes or machine tools, and has for its principal object to provide means whereby the guide surfaces formed thereon for the slides carried thereon may be effectively protected from risk of damage arising from dirt, or metal chips, or by contact with work during the process of setting up or taking down the latter. According to this invention, there are combined with the bed of the machine two sets of guides, A, A2, B, B2, parallel to one another, one set for each slide, which slides are at each end provided with extensions D2, E2, to cover

Fig. 1.

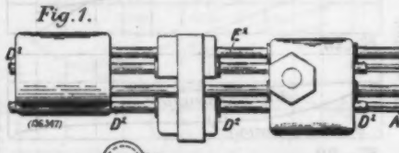
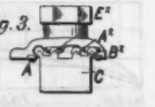


Fig. 2.

Fig. 3.

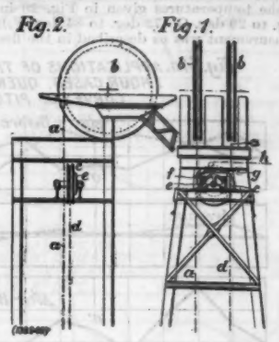


and make contact with their respective guides, and have channels formed in their undersides to receive the extensions carried by the adjacent slide, and to allow them to travel therein as the two slides approach to, or recede from one another. The invention further provides for the formation of channels G2, in the underside of the headstock, such that the extensions D2, E2 aforesaid on the slides can also travel therein as the slides are moved along their guides. By this construction the extensions can be made of such a length that the whole of the guides are covered when the slides are in certain predetermined positions. (*Sealed.*)

MINING, METALLURGY, AND METAL WORKING.

136,949. J. Morris, Maesteg, Glamorgan. Safety Appliances. (2 *Figs.*) February 15, 1919.—A safety appliance for mine cages consists of an auxiliary cable, secured at each end respectively to a mine cage and led over a sheave in the pithead frame, provided with a brake drum to which a braking surface is automatically applied to arrest the cages on release of a weighted lever controlled from the engine-house. *a* are the two usual winding ropes, each secured to the bridle chains of a mine cage, respectively, and suspending and lowering and raising said cages in the usual manner. These winding ropes *a* are each led respectively over a separate winding sheave *b* at the head of the pithead frame. Mounted high up in the pithead frame is a sheave *c*, over which is led an auxiliary cable *d*, the two ends of which are

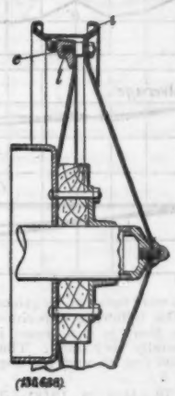
Fig. 2. *Fig. 1.*



secured each to the bridle chains of one of the mine cages respectively. The auxiliary cable *d* will run over its sheave *c* in accordance with the movements of the oppositely-travelling mine cages. Should one of the main cables *a* break, the auxiliary cable *d* will support the cage thereof by virtue of its attachment also to the other cage. The sheave *c* is provided with a brake drum *e*, against which brake blocks *f* are arranged to be pressed by a weighted lever *g*, when this latter is permitted to drop on slackening a cable *h*, under the control of the engineman in the engine-house containing the winding engines of the main winding ropes *a*. (*Accepted January 7, 1920.*)

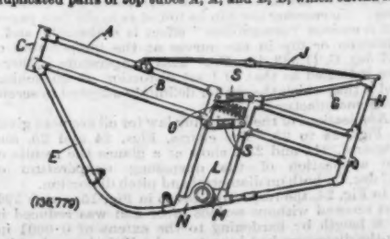
MOTOR ROAD VEHICLES.

136,688. W. Dukes, Birmingham, and The Warland Dual Rim Company, Limited, Birmingham. Vehicle Wheels. (3 *Figs.*) January 23, 1919.—The invention relates to road vehicle wheels of the type in which a rim carrying a pneumatic tyre is removably mounted between a fixed and a detachable flange on the wheel, and in which there are formed integrally



from a metal sheet, the fixed flange, the rim carrying the removable ring, and the web or wheel centre. The invention comprises the provision between the rim and web of the fixed flange, of stiffening ribs *e*, and the attachment to some or all of such ribs of studs *l* for securing the detachable flange *i*. (*Sealed.*)

136,779. H. Reed, Manchester. Motor Cycle Frames. (3 *Figs.*) July 9, 1919.—The invention relates to frames for motor cycles of the kind which are roughly triangular in outline, with a structure at the back between which and the top tubes is a saddle-carrying sling. According to the invention, the rear part of the frame is separate from the front part and is pivoted thereto at the bottom, with a spring connection between the two frame parts at the top, the saddle sling being supported on both frame parts. The frame is divided into two parts, each having duplicated pairs of top tubes A, A, and B, B, which extend from



the steering head C to the rear of the frame. The bottom tubes E are partly on the front frame and partly on the rear frame. At the top of the rear frame a structure G, H, is attached, and to this resilient slings J are attached, the forward ends of which are secured to the front tubes A. These slings carry the saddle. The two frame parts are pivoted together at L, each part having a pair of overlapping plates between which are ball races and connecting bolts. At the top the two parts are connected together by telescopic links S and a compression spring O lies between the two parts. (*Sealed.*)